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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: S. Sugarman
KENICHI KIMURA, ET AL.	)	
	:	Group Art Unit: 2873
Appln. No.: Unassigned (Divisional of Appln. No. 09/612,290 filed July 7, 2000)	) :) :) :	
Filed: January 14, 2002	))	
For: REFLECTING TYPE OPTICAL SYSTEM	:)	January 14, 2002

Commissioner for Patents
BOX PATENT APPLICATION
Washington, DC 20231

PRELIMINARY AMENDMENT

Sir:

Prior to examination on the merits, please amend the above-identified application as follows:

IN THE ABSTRACT:

Please replace the Abstract of the Disclosure with the following:

--ABSTRACT OF THE DISCLOSURE

A reflecting-type optical system according to the invention includes an optical element composed of a transparent body having an entrance surface, an exit surface and at least three curved reflecting surfaces of internal reflection. A light beam coming from an object and entering at the entrance surface is reflected from at least one of the reflecting

surfaces to form a primary image within the optical element and is, then, made to exit from the exit surface through the remaining reflecting surfaces to form an object image on a predetermined plane. In the optical system, 70% or more of the length of a reference axis in the optical element lies in one plane.--.

IN THE SPECIFICATION:

Please amend the specification as follows:

On page 2, before line 1, insert the paragraph:

--This application is a division of Application No. 09/612,290 filed July 7, 2000, which is a division of Application No. 08/606,824 filed February 26, 1996.--

Please substitute the following paragraph for the paragraph starting at page 2, line 1 and ending at line 1. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Background of the Invention.

Please substitute the following paragraph for the paragraph starting at page 2, line 2 and ending at line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Field of the Invention.

Please substitute the following paragraph for the paragraph starting at page 2, line 11 and ending at line 11. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Description of the Related Art.

Please substitute the following paragraph for the paragraph starting at page 2, line 12 and ending at line 17. A marked-up copy of this paragraph, showing the changes made thereto is attached.

There have been many previous proposals for utilizing the reflecting surfaces of convex and concave mirrors in the optical system for an image pickup apparatus. Fig. 24 schematically shows a so-called mirror optical system composed of one concave mirror and one convex mirror.

Please substitute the following paragraph for the paragraph starting at page3, line 15 and ending at line 21. A marked-up copy of this paragraph, showing the changes made thereto is attached.

However, the Cassegrainian reflecting telescopes and like mirror optical systems generally suffer a problem due to the vignetting effect by the convex mirror 102, as the object light beam is partly mutilated. This problem will exist so long as the convex mirror 102 is laid at the central passage of the object beam 104.

Please substitute the following paragraph for the paragraph starting at page 3, line 22 and ending at line 28. A marked-up copy of this paragraph, showing the changes made thereto is attached.

To solve this problem, the reflecting mirror may be decentered, thus avoiding obstruction of the passage of the object beam 104 by the unintegrated part of the optical system. In other words, the principal ray 106 of the light beam is dislocated away from an optical axis 105. Such an optical system, too, has previously been proposed.

Please substitute the following paragraph for the paragraph starting at page 5, line 23 and ending at page 6, line 4. A marked-up copy of this paragraph, showing the changes made thereto is attached.

These reflecting type photographic optical systems, because they have a great number of constituent parts, require highly precise assembly of the individual optical parts to insure satisfactory optical performance. In particular, because the tolerance for the relative positions of the reflecting mirrors is severe, later adjustment of the position and angle of orientation of each reflecting mirror is indispensable.

Please substitute the following paragraph for the paragraph starting at page 6, line 14 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

These prisms are made by molding techniques to unify the plurality of reflecting surfaces. Therefore, all the reflecting surfaces take their relative positions in so much good accuracy as to obviate the necessity of adjusting the positions of the reflecting surfaces relative to one another. However, the main function of these prisms is to change the direction of travel of light for the purpose of inverting the image. Every reflecting surface is, therefore, made to be a flat surface.

Please substitute the following paragraph for the paragraph starting at page 6, line 24 and ending at line 26. A marked-up copy of this paragraph, showing the changes made thereto is attached.

For the counterpart to this, there is also known an optical system by giving curvature to the reflecting surface of the prism.

Please substitute the following paragraph for the paragraph starting at page 8, line 2 and ending at line 11. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In this system, a light beam 154 from an information display 150 enters a prism Pa at a flat surface 157 and is incident on a paraboloidal reflecting surface 151. Being reflected from this surface 151, the display light beam 154 becomes a converging beam. Before the display light beam 154 forms an image on a focal plane 156, three total reflections occur as the beam 154 travels between two parallel flat surfaces 157 and 158 of the prism Pa. A thinning of the entirety of the optical system is thus achieved.

Please substitute the following paragraph for the paragraph starting at page 8, line 22 and ending at line 11. A marked-up copy of this paragraph, showing the changes made thereto is attached.

From the focal plane 156, the display light beam 154 exits as a diverging beam and, while repeating total reflection from the flat surfaces 157 and 158, goes on until it is incident on a paraboloidal surface 152. Since this surface 152 is a half-mirror, the beam 154 is reflected and, at the same time, undergoes its refractive power, forming an enlarged virtual image of the display and becoming a nearly parallel beam. After having penetrated the surface 157, the beam 154 enters the pupil 153 of the observer. Thus, the observer looks at the display image on the background of the external field or landscape.

Please substitute the following paragraph for the paragraph starting at page 9, line 18 and ending at page 10, line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached.

It should be also noted that the known reflecting-type photographic optical systems are adapted for application to the so-called telephoto type of lens systems as this type has a long total length and a small field angle. To attain a photographic optical system handling

field angles from the standard lens to the wide-angle lens, which require an increasing number of reflecting surfaces for correcting aberrations, the parts must be manufactured even more precisely and assembled with even severer a tolerance. Therefore, production costs rise. Otherwise, the size of the entire system tends to increase largely.

Please substitute the following paragraph for the paragraph starting at page 10, line 23 and ending at page 11, line 7. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A plurality of reflecting surfaces of curved and flat shapes are formed in unison to produce an optical element. By using a plurality of such optical elements, a mirror optical system is constructed to minimize its size. At the same time, the position and orientation tolerances (assembling tolerances) for the reflecting mirrors are made looser than was heretofore usually necessary mirror optical systems. It is, therefore, a first object of the invention to provide a highly accurate optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 11, line 8 and ending line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A stop is located at a position nearest the object side in the optical system, and an object image is formed at least once within the optical system. With this, even in a reflecting-type wide angle optical system, the effective diameter of the optical system is shortened. Moreover, a plurality of reflecting surfaces constituting the optical element are given appropriate refractive powers and the reflecting surfaces constituting every optical system are arranged in decentering relation to thereby zigzag the optical path in the optical system to a desired conformation, thus shortening the total length of the optical system in a

certain direction. It is, therefore, a second object of the invention to provide a compact optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 11, line 24 and ending at page 12, line 8. A marked-up copy of this paragraph, showing the changes made thereto is attached.

To attain the above objects, a reflecting-type optical system according to the invention comprises an optical element composed of a transparent body having an entrance surface, an exit surface and at least three curved reflecting surfaces of internal reflection, wherein a light beam coming from an object and entering at the entrance surface is reflected from at least one of the reflecting surfaces to form a primary image within the optical element and is, then, made to exit from the exit surface through the remaining reflecting surfaces to form an object image on a predetermined plane, and wherein 70% or more of the length of a reference axis in the optical element lies in one plane.

Please substitute the following paragraph for the paragraph starting at page 13, line 23 and ending at line 24. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the optical element, an entering reference axis and an exiting reference axis are orthogonal to each other;

Please substitute the following paragraph for the paragraph starting at page 14, line 25 and ending at page 15, line 6. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Another reflecting type optical system according to the invention comprises an optical element having at least three curved reflecting surfaces of surface reflection whose reference axis lies on one plane and which are formed in unison so as to be opposed to each

other, wherein a light beam coming from an object is reflected from at least one of the three curved reflecting surfaces to form an object image and the object image is then re-formed in a contracted fashion on a predetermined plane by the remaining reflecting surfaces.

Please substitute the following paragraph for the paragraph starting at page 17, line 3 and ending at line 16. A marked-up copy of this paragraph, showing the changes made thereto is attached.

A further optical system of reflecting type according to the invention comprises an optical element having formed therein in unison at least three curved reflecting surfaces composed of surface-reflecting mirrors and a reflecting surface whose normal line at a point of intersection with a reference axis is inclined with respect to a plane in which the reference axis among the plurality of reflecting surfaces lie, wherein, as a light beam coming from an object repeats reflection from the plurality of reflecting surfaces and then exits to form an image of the object, the object beam coming from the object is once focused to form an object image in one of spaces among the plurality of reflecting surfaces and is then focused to re-form the object image.

Please substitute the following paragraph for the paragraph starting at page 19, line 4 and ending at line 4. A marked-up copy of this paragraph, showing the changes made thereto is attached.

<u>Brief Description of the Drawings:</u>

Please substitute the following paragraph for the paragraph starting at page 19, line 12 and ending at line 13. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 4A-4F are graphs of lateral aberrations of the embodiment 1.

Please substitute the following paragraph for the paragraph starting at page 19, line 17 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 6A-6F are graphs of lateral aberrations of the embodiment 2.

Please substitute the following paragraph for the paragraph starting at page 19, line 22 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 8A-8F are graphs of lateral aberrations of the embodiment 3.

Please substitute the following paragraph for the paragraph starting at page 19, line 27 and ending at page 20, line 1. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 10A-10F are graphs of lateral aberrations of the embodiment 1.

Please substitute the following paragraph for the paragraph starting at page 20, line 2 and ending at line 4. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 11A and 11B are a sectional views in the YZ plane and a side elevation view of an embodiment 5 of the optical system according to the invention.

Please substitute the following paragraph for the paragraph starting at page 20, line 7 and ending at line 8. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 13A-13F are graphs of lateral aberrations of the embodiment 5.

Please substitute the following paragraph for the paragraph starting at page 20, line 12 and ending at line 13. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 15A-15F are graphs of lateral aberrations of the embodiment 6.

Please substitute the following paragraph for the paragraph starting at page 20, line 17 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 17A-17F are graphs of lateral aberrations of the embodiment 7.

Please substitute the following paragraph for the paragraph starting at page 20, line 22 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 19A-19F are graphs of lateral aberrations of the embodiment 8.

Please substitute the following paragraph for the paragraph starting at page 20, line 27 and ending at line 28. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 21A-21F are graphs of lateral aberrations of the embodiment 9.

Please substitute the following paragraph for the paragraph starting at page 21, line 4 and ending at line 5. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Figs. 23A-23F are graphs of lateral aberrations of the embodiment 10.

Please substitute the following paragraph for the paragraph starting at page 21, line 25 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Detailed Description of the Preferred Embodiments:

Please substitute the following paragraph for the paragraph starting at page 22, line 12 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 1, the first surface R1 is a stop, the second surface R2 is a refracting surface coaxial to the first surface, the third surface R3 is a reflecting surface tilted relative to the second surface R2, the fourth surface R4 and the fifth surface R5 each are a reflecting surface shifted and tilted relatively to the respective preceding surface, and the sixth surface R6 is a refracting surface shifted and tilted relatively to the fifth surface R5. All of the second to sixth surfaces R2 to R6 are formed on a substrate of glass, plastic or like medium to form a single optical element indicated by reference numeral 10.

Please substitute the following paragraph for the paragraph starting at page 25, line 5 and ending at line 13. A marked-up copy of this paragraph, showing the changes made thereto is attached.

To express the shape of the i-th surface constituting part of the optical system, the absolute coordinate system is not as suitable for the purpose of better understanding as using a local coordinate system whose original point is taken at the point of intersection of the reference axis with the i-th surface. In the specific embodiments of the invention, therefore, the numerical data of the design parameters for the i-th surface are given by using the local coordinate system.

Please substitute the following paragraph for the paragraph starting at page 26, line 17 and ending at line 26. A marked-up copy of this paragraph, showing the changes made thereto is attached.

The optical system of each of the embodiments of the invention has a spheric surface and an aspheric surface which is rotationally asymmetric. Of these, the spheric ones are expressed as the spheres described by the radius of curvature Ri. The radius of curvature Ri is given a minus sign when the center of curvature lies on the first surface side in the reference axis (the dot-and-dash lines in Fig. 1) oriented from the first surface to the image plane, or a plus sign when on the image plane side.

Please substitute the following paragraph for the paragraph starting at page 27, line 12 and ending at line 17. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Since the surface equation described above contains only the terms of even number orders in respect to x, the surface defined by such an equation takes the YZ plane as a plane of symmetry so it has the shape of symmetry with respect to a plane. Further, in a case where the following conditions are satisfied, $C_{03} = C_{2}, = 0$, $t = 0$ its shape is symmetrical with respect to the XZ plane. Further, in a case where the following conditions are satisfied,

Please substitute the following paragraph for the paragraph starting at page 31, line 21 and ending at page 32, line 14. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig.2, an optical element 10 has a plurality of curved reflecting surfaces and is made from a glass or like transparent body. The external surface of the optical element 10 is constructed, as comprising, in order of passage of the ray from an object, a refracting surface R2 (entrance surface) having a negative refractive power in concave form toward

the object side, four reflecting surfaces, namely, a concave mirror R3 for giving convergence to the ray, a reflecting surface R4, a reflecting surface R5 and a concave mirror R6, and a refracting surface R7 (exit surface) having a positive refractive power in convex form toward the image side. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A quartz low-pass filter, infrared cut filter or like optical correction plate 3 is located in front of a last image plane R10 which is coincident with the image sensing surface of a CCD or like image pickup element (or recording medium). A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 33, line 12 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In such a manner, the optical element 10, owing to the refractive powers by the entrance and exit surfaces and to the refractive powers in the interior thereof by the plurality of curved reflecting mirrors, functions as a lens unit having the desired optical performance with the overall refractive power being positive.

Please substitute the following paragraph for the paragraph starting at page 33, line 19 and ending at page 34, line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the present embodiment, focusing on a close object is performed by moving the whole optical system relative to the image sensing surface R10 of the image pickup element. Particularly in the present embodiment, because the direction of the reference axis entering the optical element 10 and the direction of the reference axis exiting from the optical element 10 are parallel to each other and are the same direction, the whole optical system can be moved in parallel to the direction of the exiting reference axis (Z axis

direction). Thus, the focusing operation can be carried out as in the conventional lens system.

Please substitute the following paragraph for the paragraph starting at page 34, line 9 and ending at line 24. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the case of the present embodiment where the entrance pupil is located in the neighborhood of the first surface R2 of the optical element 10, particularly the fact that the first curved reflecting surface R3, when counted from the object side, is given the converging action, contributes to a reduction of the size of the optical system. In more detail, the pupil ray (principal ray) is caused to form the intermediate image in the stage near to the entrance surface, thereby further reducing the thickness of the optical system. After having exited from the stop R1 and before expanding largely, the off-axial principal ray is made to converge. With this, when increasing the angle of view of the optical system, the increase of the effective diameters of the first reflecting surface R3 and those that follow is suppressed.

Please substitute the following paragraph for the paragraph starting at page 37, line 10 and ending at line 22. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the present embodiment, the entrance surface R2 and the exit surface R7 of the optical system 10 have refractive powers (optical powers). In the present embodiment, the entrance surface R2 is made to be a concentric concave surface with the off-axial principal ray, thereby reducing the various off-axial aberrations. Also, the exit surface R7 is formed to a convex shape toward the image side, thereby preventing the back focal distance from becoming too long. On the other hand, if the entrance surface R2 is made convex toward

the object side, the off-axial rays converges in crossing this surface. Therefore, the first reflecting surface R3 can be prevented from increasing in size.

Please substitute the following paragraph for the paragraph starting at page 37, line 23 and ending at page 38, line 10. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Also, the shape of the exit surface R7 is determined so that the off-axial principal ray (pupil ray) to this surface is to exit therefrom (to the image side) in almost parallel, regardless of the angle of incidence, that is, to be telecentric. This produces an advantage when an image pickup element such as a CCD is used. In this case, there is a gap between the color filter of the CCD and the light receiving surface. Therefore, the color separation would otherwise vary with variation of the angle of incidence on the image pickup element. As the optical system is made telecentric to the image side, the principal rays of the on-axial and off-axial light beams both become almost parallel to the optical axis. Therefore, the angle of incidence on the CCD becomes almost constant over the entire area of the light receiving surface.

Please substitute the following paragraph for the paragraph starting at page 39, line 27 and ending at page 40, line 9. A marked-up copy of this paragraph, showing the changes made thereto is attached.

The reflecting surfaces constituting the optical system each have its normal line at the point of intersection of the entering and exiting reference axis to be out of coincidence with the direction of the reference axis, or are the so-called decentering reflecting surface. This is for the purpose of preventing the vignetting effect from being produced as in the conventional mirror optical system. At the same time, a free configuration can be adopted. So, an optical element of good space efficiency, compact form and free shape can be made.

Please substitute the following paragraph for the paragraph starting at page 40, line 10 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Further, the shape of each of the reflecting surfaces has different radii of curvature in the orthogonal two planes (yz plane and xz plane). This is for the purpose of suppressing the decentering aberrations produced by the decentering arrangement of each reflecting surface. Further, this reflecting surface is made asymmetric, thereby well correcting various aberrations. A desired optical performance is thus achieved.

Please substitute the following paragraph for the paragraph starting at page 43, line 12 and ending at page 44, line 3. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 5, an optical element 10 has a plurality of curved reflecting surfaces and is made from a glass or like transparent body. The external surface of the optical element 10 is made, as comprising, in order of passage of light from an object, a refracting surface R2 (entrance surface) having a negative refractive power in concave form toward the object side, five reflecting surfaces, namely, a concave mirror R3 for giving convergence to the light rays, a convex mirror R4 for giving divergence, a concave mirror R5 for giving convergence, a reflecting surface R6 for giving convergence and a concave mirror R7, and a refracting surface R8 (exit surface) having a positive refractive power in convex form toward the image side. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 45, line 2 and ending at line 12. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the present embodiment, focusing to a close object is performed by moving the whole optical system relative to the image receiving surface R10 of the image pickup element. Particularly in the present embodiment, because the direction of the reference axis entering the optical element 10 and the direction of the reference axis exiting from the optical element 10 are parallel, the whole optical system can be moved in parallel to the direction of the exiting reference axis (Z axis direction), so that the focusing operation is carried out as in the conventional lens system.

Please substitute the following paragraph for the paragraph starting at page 45, line 17 and ending at line 22. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Besides these, in the present embodiment, because the entrance and exit surfaces for the optical element 10 are arranged on one side thereof, it is possible to make an optical system of reduced width in the X direction with the total length in the direction of the Z axis (+) being minimized.

Please substitute the following paragraph for the paragraph starting at page 48, line 11 and ending at line 26. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 7, an optical element 10 has a plurality of curved reflecting surfaces and is made from a glass or like transparent body. The external surface of the optical element 10 is made, in order of passage of light from an object of, a convex refracting surface R2 (entrance surface) having a positive refractive power, six reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5, a reflecting surface R6, a

concave mirror R7 and a convex mirror R8, and a convex refracting surface R9 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R10 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 52, line 4 and ending at line 19. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 9, an optical element 10 has a plurality of curved reflecting surfaces and is made from glass or like transparent body. The external surface of the optical element 10 is made, in order of passage of light from an object of, a concave refracting surface R2 (entrance surface) having a negative refractive power, four reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5 and a reflecting surface R6, and a convex refracting surface R7 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 54, line 10 and ending at line 27. A marked-up copy of this paragraph, showing the changes made thereto is attached.

As far as the present embodiment is concerned, there are two ways of tilting each surface, one of which is in the XZ plane and the other in the XY plane. Accordingly, the local coordinate system should otherwise be defined. The angle to which the i-th surface is first tilted in the XZ plane is expressed by ϕi (in units of degree) with the clockwise

direction as viewed from the plus direction of the Y axis being taken as positive, and then in the XY plane by θi (in units of degree) with the counterclockwise direction as viewed from the plus direction of the Z axis being taken as positive. For the axes of the local coordinates (x,y,z) for the i-th surface to define in relation to the absolute coordinate system (X,Y,Z), suppose the local coordinate system is first moved until its original point coincides with a point (Xi,Yi,Zi), then turned in the XZ plane to the angle ϕi and, at last, turned in the XY plane to the angle θi, the following settings are thus obtained:

Please substitute the following paragraph for the paragraph starting at page 57, line 7 and ending at line 23. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Figs. 11A and 11B, an optical element 10 has a plurality of curved reflecting surfaces and is made from glass or like transparent body. The external surface of the optical element 10 is made, as, in order of passage of light from an object of, a convex refracting surface R2 (entrance surface) having a positive refractive power, six reflecting surfaces, namely, a flat reflecting plane R3, a concave mirror R4, a convex mirror R5, a concave mirror R6, a reflecting surface R7 and a concave mirror R8, and a convex refracting surface R7 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 58, line 25 and ending at page 59, line 3. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the case of the present embodiment, the entrance surface R2 of the optical element 10 is made to have a relatively strong positive refractive power, thereby

condensing the on-axial and off-axial light beams. The flat reflecting surface R3 is thus prevented from increasing in the size. This achieves a further thinning of the whole optical system.

Please substitute the following paragraph for the paragraph starting at page 59, line 10 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the preceding embodiments, all of the reference axes, including the entering reference axis, and the exiting reference axis are contained in a certain plane (YZ plane). From the point of view of the layout of the photographic optical system, it is desirable in some cases that the entering reference axis is not in parallel with that plane. So, in the case of the present embodiment, the thinning is possible in the perpendicular direction (in this instance, the Z axis direction) to the plane in which the zigzagged reference axis of the interior of the optical system is contained likewise as in the other embodiments. Because of this, a photographic optical system of reduced thickness in the shooting direction can be formed. So, the degree of freedom for incorporating the optical system into the camera or the like is further increased.

Please substitute the following paragraph for the paragraph starting at page 62, line 16 and ending at page 63, line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 14, a block 60 of hollow core (optical element) has a plurality of curved reflecting surfaces formed in the interior thereof. The internal surface of the optical element 60 is made, in order of passage of light from an object of, four reflecting surfaces, namely, a concave mirror R2, reflecting surfaces R3 and R4 and a concave mirror R5. A stop R1 (entrance pupil) is located on the object side of the optical element 60. A last image plane R6 is coincident with the image sensing surface of a CCD or like image

pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 66, line 11 and ending at line 26. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 16, a block 60 of hollow core (optical element) has a plurality of curved reflecting surfaces formed in the interior thereof. Two positive lenses 71 and 72 (refracting optical systems) are located at the entrance and exit of the optical element 60, respectively. The internal surface of the optical element 60 is made, in order of passage of light from an object of, four reflecting surfaces, namely, a concave mirror R4, a convex mirror R5, a concave mirror R6 and a reflecting surface R7. A stop R1 (entrance pupil) is located on the object side of the positive lens 71. A last image plane R10 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 67, line 21 and ending at line 27. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Owing to such refractive powers in the interior of the optical element 60 by the plurality of curved reflecting mirrors, and to such refractive powers by the two positive lenses 71 and 72, the optical system 70 functions as a lens unit having a desired optical performance with the overall refractive power being positive.

Please substitute the following paragraph for the paragraph starting at page 70, line 18 and ending at page 71, line 8. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 18, an optical element 10 has two refracting surfaces and a plurality of curved reflecting surfaces and is made from glass or like transparent body. The external surface of the optical element 10 is made, in order of passage of light from an object of, a concave refracting surface R2 (entrance surface) having a negative refractive power, four reflecting surfaces, namely, a concave mirror R3, a reflecting surface R4, a reflecting surface R5 and a concave mirror R6, and a concave refracting surface R7 (exit surface) having a negative refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 72, line 18 and ending at line 24. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Fig. 20 is a sectional view in the YZ plane of a ninth embodiment of the optical system according to the invention . The present embodiment is a photographic optical system of 63.4 degrees in the horizontal angle of view and 49.6 degrees in the vertical angle of view. Fig. 20 also shows the optical path. The data of the design parameters of the present embodiment are as follows:

Please substitute the following paragraph for the paragraph starting at page 74, line 18 and ending at page 75, line 6. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 20, an optical element 10 has a plurality of curved reflecting surfaces and is made from glass or like transparent body. The external surface of the optical element 10 is made, in order of passage of light from an object of, a convex refracting surface R2 (entrance surface) having a positive refractive power, five reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5, a reflecting surface R6 and a concave mirror R7, and a convex refracting surface R8 (exit surface) having a positive refractive power. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 76, line 21 and ending at page 77, line 3. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the present embodiment, the entrance surface R2 is made to be a convex refracting surface of sphere, thereby converging the off-axial principal ray. With this, when increasing the angle of field, the size of the first reflecting surface R3 is prevented from becoming big. The exit surface R8, too, is made to be a convex refracting surface of sphere, thereby preventing the back focal distance from increasing too much. At the same time, the off-axial rays are controlled so that the off-axial principal ray becomes telecentric to the image side.

Please substitute the following paragraph for the paragraph starting at page 77, line 5 and ending at line 11. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Fig. 22 is a sectional view in the YZ plane of a tenth embodiment of the optical system according to the invention. The present embodiment is a photographic optical system of 63.4 degrees in the horizontal angle of view and 49.6 degrees in the vertical angle of view. In Fig. 22, the optical path is also shown. The data of the design parameters of the present embodiment are as follows:

Please substitute the following paragraph for the paragraph starting at page 79, line 6 and ending at line 20. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In Fig. 22, an optical element 10 has a plurality of curved reflecting surfaces and is made from glass or like transparent body. The external surface of the optical element 10 is made, in order of passage of light from an object of, a convex refracting surface R2 (entrance surface) having a positive refractive power, five reflecting surfaces, namely, a concave mirror R3, reflecting surfaces R4, R5 and R6 and a concave mirror R7, and a concave refracting surface R8 (exit surface) having a negative refractive power. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 81, line 9 and ending at line 19. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the present embodiment, the entrance surface R2 is made to be a convex refracting surface of a sphere, thereby converging the off-axial principal ray. With this,

when increasing the angle of field, the effective diameter of the first reflecting surface R3 is prevented from increasing in size. Also, the exit surface R8 is made to be a concave refracting surface of sphere. With this arrangement, for the on-axial rays, a long back focal distance is secured, and, for the off-axial rays, it becomes telecentric to the image side.

Please substitute the following paragraph for the paragraph starting at page 84, line 9 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

With the use of the optical elements each having a plurality of reflecting surfaces of curved and flat shapes formed in unison, the compact form of the entirety of the mirror optical system is improved, while still permitting the position and angle tolerances (assembling tolerances) for the reflecting mirrors to be made looser than was heretofore usually necessary to the mirror optical systems. Hence, it is possible to achieve a highly accurate optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 85, line 10 and ending at line 25. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the case of the embodiments either when the stop is ahead of the optical element, or when the entrance pupil lies on the object side of the first reflecting surface, when counted from the object side of the optical element, particularly the impartment of the converging function to the first reflecting surface of the optical element contributes to a reduction of the size of the optical system, since the pupil ray (principal ray) forms the intermediate image in the stage near to the entrance surface, so that a further thinning of the optical system is assured. After having exited from the stop R1 and before diverging largely, the off-axial principal ray is made to converge. With this, when increasing the

angle of view of the optical system, the increase of the effective diameters of the first reflecting surface and those that follow is suppressed.

Please substitute the following paragraph for the paragraph starting at page 87, line 10 and ending at line 18. A marked-up copy of this paragraph, showing the changes made thereto is attached.

Further, in the embodiments, whilst almost every reflecting surfaces has only one plane of symmetry, the entrance and exit surfaces are of rotationally symmetric form with respect to the reference axis. By virtue of this, the reference axis can be accurately measured and tested when manufacturing the optical systems. Also, by making the refracting surface to be rotationally symmetric, the amount of produced asymmetric chromatic aberrations can be reduced.

Please substitute the following paragraph for the paragraph starting at page 88, line 20 and ending at page 89, line 2. A marked-up copy of this paragraph, showing the changes made thereto is attached

The reflecting surfaces constituting the optical element each have its normal line at the point of intersection of the entering and exiting reference axis to be out of coincidence with the direction of the reference axis, or are the so-called decentered reflecting surface. This is for the purpose of preventing the vignetting effect from being produced as in the conventional mirror optical system. At the same time, by this, a free layout can be adopted. So, an optical element of good space efficiency, compact form and free shape can be made up.

Please substitute the following paragraph for the paragraph starting at page 90, line 24 and ending at page 91, line 3. A marked-up copy of this paragraph, showing the changes made thereto is attached

In more detail, according to the invention, a wide variety of forms of optical elements can be obtained with the orientation of the entering reference axis different from that of the exiting reference axis. By virtue of a high degree of freedom for the layout, therefore, it becomes possible to adopt the most suitable form of the photographic optical system for the camera or the like apparatus.

IN THE CLAIMS:

Please cancel Claims 1 through 51 without prejudice to or disclaimer of the subject matter recited therein. Please add new Claims 52 through 58 as follows:

--52. (New) An optical system forming an image of an object, comprising:

at least three curved reflecting surfaces, at least one curved reflecting surface of said at least three curved reflecting surfaces having a shape of rotational asymmetry,

wherein an object ray reflected from at least one curved reflecting surface of said at least three curved reflecting surfaces temporarily forms a real image of the object in an optical path of said optical system, and a pupil ray reflected from at least one curved reflecting surface of said at least three curved reflecting surfaces forms a real image of a pupil in an optical path of said optical system.

53. (New) An optical system according to Claim 52, further comprising an optical unit including said at least three curved reflecting surfaces,

wherein the object ray forms a real image of the object in said optical unit, and the pupil ray forms a real image of the pupil in said optical unit.

54. (New) An optical system according to Claim 53, wherein said optical unit is one optical element composed of a transparent medium, and said at least three curved reflecting surfaces are internal reflection surfaces provided in the optical element.

55. (New) An optical system according to Claim 52, wherein said at least three curved reflecting surfaces have a shape of rotational asymmetry.

56. (New) An optical system according to Claim 55, wherein said at least three curved reflecting surfaces have a shape of symmetry with respect to only one symmetry plane.

57. (New) An optical system according to Claim 52, wherein an entrance pupil of said optical system is disposed nearer to the light entrance side than a reflecting surface, which is disposed nearest to the light entrance side among the curved reflecting surfaces included in said optical system.

58. (New) An image pickup apparatus, comprising an optical system forming an image of an object, said optical system comprising:

at least three curved reflecting surfaces, at least one curved reflecting surface of said at least three curved reflecting surfaces having a shape of rotational asymmetry, wherein an object ray reflected from at least one curved reflecting surface of said at least three curved reflecting surfaces temporarily forms a real image of the object in an optical path of said optical system, and a pupil ray reflected from at least one curved reflecting surface of said at least three curved reflecting surfaces forms a real image of a pupil in an optical path of said optical system; and

an image pickup medium in which an image sensing surface is arranged at a position where an image of an object is formed by said optical system.--.

REMARKS

This is a divisional application of Application No. 09/612,290 filed July 7, 2000 (the '290 Application), which is a divisional of Application No. 08/606,824 filed February 26, 1996 (the "'824 Application").

Claims 52 through 58 are pending, with Claims 52 and 58 being independent. Claims 1 through 51 have been cancelled without prejudice.

The specification and Abstract have been amended to include changes made in the '824 Application and the '290 Application.

Also enclosed is an Information Disclosure Statement citing the art of record in the parent and grandparent applications, a Request for Approval to Amend the Drawings, and corrected formal drawings.

Applicants claim priority under 35 U.S.C. § 119 based upon Japanese Priority Application Nos. 7-065109 filed February 28, 1995, and 7-123238 filed April 24, 1995, and respectfully request acknowledgment of this claim and of receipt of the certified copies of the priority documents, which were filed July 23, 1996, in the '824 Application.

Applicants' undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

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Appln. No. Div. of 09/612,290
Atty. Docket No. 00865.004059.2

VERSION SHOWING CHANGES MADE TO SPECIFICATION

On page 2, before line 1, insert the paragraph:

--This application is a division of Application No. 08/606,824 filed February 26, 1996.--

Please substitute the following paragraph for the paragraph starting at page 2, line 1 and ending at line 1.

[Background of the Invention.] Background of the Invention.

Please substitute the following paragraph for the paragraph starting at page 2, line 2 and ending at line 2.

[Field of the Invention.] Field of the Invention.

Please substitute the following paragraph for the paragraph starting at page 2, line 11 and ending at line 11.

[Description of the Related Art.] Description of the Related Art.

Please substitute the following paragraph for the paragraph starting at page 2, line 12 and ending at line 17.

There have been many previous proposals for utilizing the reflecting surfaces of convex and concave mirrors in the optical system for an image pickup apparatus. Fig. 24 schematically shows a so-called mirror optical system composed of one concave mirror and one convex mirror.

Please substitute the following paragraph for the paragraph starting at page 3, line 15 and ending at line 21.

However, the Cassegrainian reflecting telescopes and like mirror optical systems generally suffer a problem due to the vignetting effect by the convex mirror 102, as the object light beam is partly mutilated. This problem will [survive] exist so long as the convex mirror 102 is laid at the central passage of the object beam 104.

Please substitute the following paragraph for the paragraph starting at page 3, line 22 and ending at line 28.

To solve this problem, the reflecting mirror may be [put] decentered, thus avoiding obstruction of the passage of the object beam 104 by the unintegrated part of the optical system. In other words, the principal ray 106 of the light beam is dislocated away from an optical axis 105. Such an optical system, too, has previously been proposed.

Please substitute the following paragraph for the paragraph starting at page 5, line 23 and ending at page 6, line 4.

These reflecting type photographic optical systems, because [of their having] they have a great number of constituent parts, [have need of increasing the precision accuracy with which to

assemble] require highly precise assembly of the individual optical parts [in order] to insure [that the] satisfactory optical performance [can be obtained]. In particular, because the tolerance for the relative positions of the reflecting mirrors is severe, later adjustment of the position and angle of orientation of each reflecting mirror is indispensable.

Please substitute the following paragraph for the paragraph starting at page 6, line 14 and ending at line 23.

These prisms are made [up by the] by molding techniques to unify the plurality of reflecting surfaces. Therefore, all the reflecting surfaces take their relative positions in so much good accuracy as to obviate the necessity of [doing any more adjustments of] adjusting the [relative] positions of the reflecting surfaces relative to one another. However, the main function of these prisms is to change the direction of travel of light for the purpose of inverting the image. Every reflecting surface is, therefore, made to be a flat surface.

Please substitute the following paragraph for the paragraph starting at page 6, line 24 and ending at line 26.

For the [counter part] counterpart to this, there is also known an optical system by giving curvature to the reflecting surface of the prism.

Please substitute the following paragraph for the paragraph starting at page 8, line 2 and ending at line 11.

In this system, a light beam 154 from an information display 150 enters a prism Pa at a flat surface 157 and is incident on a paraboloidal reflecting surface 151. Being reflected from this surface 151, the display light beam 154 becomes a converging beam. Before the display light beam 154 forms an image on a focal plane 156, three total reflections [occurs] <u>occur</u> as the beam 154 travels between two parallel flat surfaces 157 and 158 of the prism Pa. A thinning of the entirety of the optical system is thus achieved.

Please substitute the following paragraph for the paragraph starting at page 8, line 22 and ending at line 11.

From the focal plane 156, the display light beam 154 exits as a diverging beam and, while repeating total reflection from the flat surfaces 157 and 158, goes on [till] <u>until</u> it is incident on a paraboloidal surface 152. Since this surface 152 is a half-mirror, the beam 154 is reflected and, at the same time, undergoes its refractive power, forming an enlarged virtual image of the display and becoming a nearly parallel beam. After having penetrated the surface 157, the beam 154 enters the pupil 153 of the observer. Thus, the observer looks at the display image on the background of the external field or landscape.

Please substitute the following paragraph for the paragraph starting at page 9, line 18 and ending at page 10, line 2.

It should be also noted that the [prior-known reflecting type] <u>known reflecting-type</u> photographic optical systems are adapted for application to the so-called telephoto type of lens systems as this type has a long total length and a small field angle. To attain a photographic

optical system [which necessitates the] handling field angles [of] from the standard lens to the wide-angle lens, [because] which require an increasing number of reflecting surfaces for correcting aberrations [is required to use], the parts must be manufactured [to] even [higher precision accuracy] more precisely and assembled with even severer a tolerance. Therefore, [the] production [cost has to be sacrificed] costs rise. Otherwise, the size of the entire system tends to increase largely.

Please substitute the following paragraph for the paragraph starting at page 10, line 23 and ending at page 11, line 7.

A plurality of reflecting surfaces of curved and flat shapes are formed in unison to produce an optical element. By using a plurality of such optical elements, a mirror optical system is constructed [with the] to minimize its size. [of its entirety shortened to a minimum.] At the same time, the position and orientation tolerances (assembling tolerances) for the reflecting mirrors [is] are made looser than was heretofore usually necessary [to the] mirror optical systems. It is, therefore, a first object of the invention to provide a [high] highly accurate optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 11, line 8 and ending line 23.

A stop is located at a position nearest [to] the object side [among] in the optical system, and an object image is formed at least once within the optical system. With this, [despite a] even in a reflecting-type wide angle optical system [of reflecting type], the effective diameter of the

optical system is shortened. Moreover, a plurality of reflecting surfaces constituting the optical element are given appropriate refractive powers and the reflecting surfaces constituting every optical system are arranged in decentering relation to thereby zigzag the optical path in the optical system to a desired conformation, thus shortening the total length of the optical system in a certain direction. It is, therefore, a second object of the invention to provide a compact optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 11, line 24 and ending at page 12, line 8.

To attain the above objects, [an] a reflecting-type optical system [of reflecting type] according to the invention comprises an optical element composed of a transparent body having an entrance surface, an exit surface and at least three curved reflecting surfaces of internal reflection, wherein a light beam coming from an object and entering at the entrance surface is reflected from at least one of the reflecting surfaces to form a primary image within the optical element and is, then, made to exit from the exit surface through the remaining reflecting surfaces to form an object image on a predetermined plane, and wherein 70% or more of the length of a reference axis in the optical element lies in one plane.

Please substitute the following paragraph for the paragraph starting at page 13, line 23 and ending at line 24.

In the optical element, an entering reference axis and an exiting reference axis [is] are orthogonal to each other;

Please substitute the following paragraph for the paragraph starting at page 14, line 25 and ending at page 15, line 6.

Another reflecting type optical system [of reflecting type] according to the invention comprises an optical element having at least three curved reflecting surfaces of surface reflection whose reference axis lies on one plane and which are formed in unison so as to be opposed to each other, wherein a light beam coming from an object is reflected from at least one of the three curved reflecting surfaces to form an object image and the object image is then re-formed in a contracted fashion on a predetermined plane by the remaining reflecting surfaces.

Please substitute the following paragraph for the paragraph starting at page 17, line 3 and ending at line 16.

A further optical system of reflecting type according to the invention comprises an optical element having formed therein in unison at least three curved reflecting surfaces composed of [surface reflecting] surface-reflecting mirrors and a reflecting surface whose normal line at a point of intersection with a reference axis is inclined with respect to a plane in which the reference axis among the plurality of reflecting surfaces lie, wherein, as a light beam coming from an object repeats reflection from the plurality of reflecting surfaces and then exits to form an image of the object, the object beam coming from the object is once focused to form an object image in one of spaces among the plurality of reflecting surfaces and is then focused to re-form the object image.

Please substitute the following paragraph for the paragraph starting at page 19, line 4 and ending at line 4.

[Brief Description of the Drawings:] Brief Description of the Drawings:

Please substitute the following paragraph for the paragraph starting at page 19, line 12 and ending at line 13.

[Fig. 4 shows] Figs. 4A-4F are graphs of lateral aberrations of the embodiment 1.

Please substitute the following paragraph for the paragraph starting at page 19, line 17 and ending at line 18.

[Fig. 6 shows] Figs. 6A-6F are graphs of lateral aberrations of the embodiment 2.

Please substitute the following paragraph for the paragraph starting at page 19, line 22 and ending at line 23.

[Fig. 8 shows] Figs. 8A-8F are graphs of lateral aberrations of the embodiment 3.

Please substitute the following paragraph for the paragraph starting at page 19, line 27 and ending at page 20, line 1.

[Fig. 10 shows] Figs. 10A-10F are graphs of lateral aberrations of the embodiment 1.

Please substitute the following paragraph for the paragraph starting at page 20, line 2 and ending at line 4.

Figs. [11a] 11A and [11b] 11B are a sectional [view] views in the YZ plane and a side elevation view of an embodiment 5 of the optical system according to the invention.

Please substitute the following paragraph for the paragraph starting at page 20, line 7 and ending at line 8.

[Fig. 13 shows] Figs. 13A-13F are graphs of lateral aberrations of the embodiment 5.

Please substitute the following paragraph for the paragraph starting at page 20, line 12 and ending at line 13.

[Fig. 15 shows] Figs. 15A-15F are graphs of lateral aberrations of the embodiment 6.

Please substitute the following paragraph for the paragraph starting at page 20, line 17 and ending at line 18.

[Fig. 17 shows] Figs. 17A-17F are graphs of lateral aberrations of the embodiment 7.

Please substitute the following paragraph for the paragraph starting at page 20, line 22 and ending at line 23.

[Fig. 19 shows] Figs. 19A-19F are graphs of lateral aberrations of the embodiment 8.

Please substitute the following paragraph for the paragraph starting at page 20, line 27 and ending at line 28.

[Fig. 21 shows] Figs. 21A-21F are graphs of lateral aberrations of the embodiment 9.

Please substitute the following paragraph for the paragraph starting at page 21, line 4 and ending at line 5.

[Fig. 23 shows] Figs. 23A-23F are graphs of lateral aberrations of the embodiment 10.

Please substitute the following paragraph for the paragraph starting at page 21, line 25 and ending at line 25.

[Detailed Description of the Preferred Embodiments:] Detailed Description of the Preferred Embodiments:

Please substitute the following paragraph for the paragraph starting at page 22, line 12 and ending at line 23.

In Fig. 1, the first surface R1 is a stop, the second surface R2 is a refracting surface coaxial to the first surface, the third surface R3 is a reflecting surface tilted [relatively] relative to the second surface R2, the fourth surface R4 and the fifth surface R5 each are a reflecting surface shifted and tilted relatively to the respective preceding surface, and the sixth surface R6 is a refracting surface shifted and tilted relatively to the fifth surface R5. All of the second to sixth surfaces R2 to R6 are formed on a substrate of glass, plastic or like medium to form a single optical element indicated by reference numeral 10.

Please substitute the following paragraph for the paragraph starting at page 25, line 5 and ending at line 13.

To express the shape of the i-th surface constituting part of the optical system, the absolute coordinate system is not as suitable for the purpose of better understanding [than] as using a local coordinate system whose original point is taken at the point of intersection of the reference axis with the i-th surface. In the specific embodiments of the invention, therefore, the numerical data of the design parameters for the i-th surface are given by using the local coordinate system.

Please substitute the following paragraph for the paragraph starting at page 26, line 17 and ending at line 26.

The optical system of each of the embodiments of the invention has a spheric surface and an aspheric [surfaces] surface which is rotationally asymmetric. Of these, the spheric ones are expressed as the spheres described by the radius of curvature Ri. The radius of curvature Ri is given a minus sign when the center of curvature lies on the first surface side in the reference axis (the dot-and-dash lines in Fig. 1) oriented from the first surface to the image plane, or a plus sign when on the image plane side.

Please substitute the following paragraph for the paragraph starting at page 27, line 12 and ending at line 17.

Since the surface equation described above contains only the terms of even number orders in respect to x, the surface defined by such an equation takes the YZ plane as a plane of symmetry so it has the shape of symmetry with respect to a plane. Further, in a case where the

following conditions are satisfied, $C_{03} = C_{2}, = 0$, $t = 0$ its shape is symmetrical with respect to the XZ plane. Further, in a case where the following conditions are satisfied,

Please substitute the following paragraph for the paragraph starting at page 31, line 21 and ending at page 32, line 14.

In Fig.2, an optical element 10 has a plurality of curved reflecting surfaces and is made [up] from a glass or like transparent body. The external surface of the optical element 10 is constructed, as comprising, in order of passage of the ray from an object, a refracting surface R2 (entrance surface) having a negative refractive power in concave form toward the object side, four reflecting surfaces, namely, a concave mirror R3 for giving convergence to the ray, a reflecting surface R4, a reflecting surface R5 and a concave mirror R6, and a refracting surface R7 (exit surface) having a positive refractive power in convex form toward the image side. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A quartz low-pass filter, infrared cut filter or like optical correction plate 3 is located in front of a last image plane R10 which is coincident with the image sensing surface of a CCD or like image pickup element (or recording medium). A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 33, line 12 and ending at line 18.

In such a manner, the optical element 10, owing to the refractive powers by the entrance and exit surfaces and to the refractive powers in the interior thereof by the plurality of curved

reflecting mirrors, functions as a lens unit having the desired optical performance with the overall refractive power being positive.

Please substitute the following paragraph for the paragraph starting at page 33, line 19 and ending at page 34, line 2.

In the present embodiment, focusing [to] on a close object is performed by moving the whole optical system relative to the image sensing surface R10 of the image pickup element. Particularly in the present embodiment, because the direction of the reference axis entering the optical element 10 and the direction of the reference axis exiting from the optical element 10 are parallel to each other and are the same direction, the whole optical system can be moved in parallel to the direction of the exiting reference axis (Z axis direction). Thus, the focusing operation can be carried out [likewise] as in the conventional lens system.

Please substitute the following paragraph for the paragraph starting at page 34, line 9 and ending at line 24.

In the case of the present embodiment where the entrance pupil is located in the neighborhood of the first surface R2 of the optical element 10, particularly the fact that the first curved reflecting surface R3, when counted from the object side, is given the converging action, contributes to a reduction of the size of the optical system. In more detail, the pupil ray (principal ray) is caused to form the intermediate image in the stage near to the entrance surface, thereby further reducing the thickness of the optical system. After having exited from the stop R1 and before expanding largely, the off-axial principal ray is made to converge. With this,

when [to increase] <u>increasing</u> the angle of view of the optical system, the increase of the effective diameters of the first reflecting surface R3 and those that follow is suppressed.

Please substitute the following paragraph for the paragraph starting at page 37, line 10 and ending at line 22.

In the present embodiment, the entrance surface R2 and the exit surface R7 of the optical system 10 have refractive powers (optical powers). In the present embodiment, the entrance surface R2 is made to be a concentric concave surface with the off-axial principal ray, thereby reducing the various off-axial aberrations. Also, the exit surface R7 is formed to a convex shape toward the image side, thereby preventing the back focal distance from becoming too long. On the other hand, if the entrance surface R2 is made convex toward the object side, the off-axial rays converges in crossing this surface. Therefore, the first reflecting surface R3 can be prevented from increasing in [its] size.

Please substitute the following paragraph for the paragraph starting at page 37, line 23 and ending at page 38, line 10.

Also, the shape of the exit surface R7 is determined so that the off-axial principal ray (pupil ray) to this surface is to exit therefrom (to the image side) in almost parallel, regardless of the angle of incidence, that is, to be telecentric. This produces an advantage when [the] <u>an</u> image pickup element such as <u>a</u> CCD is used. In this case, there is a gap between the color filter of the CCD and the light receiving surface. Therefore, the color separation would otherwise vary with variation of the angle of incidence on the image pickup element. As the optical system is made

telecentric to the image side, the principal rays of the on-axial and off-axial light beams both become almost parallel to the optical axis. Therefore, the angle of incidence on the CCD becomes almost constant over the entire area of the light receiving surface.

Please substitute the following paragraph for the paragraph starting at page 39, line 27 and ending at page 40, line 9.

The reflecting surfaces constituting the optical system each have its normal line at the point of intersection of the entering and exiting reference axis to be out of coincidence with the direction of the reference axis, or are the so-called decentering reflecting surface. This is for the purpose of preventing the vignetting effect from being produced as in the conventional mirror optical system. At the same time, a free configuration can be adopted. So, an optical element of good space efficiency, compact form and free shape can be made [up].

Please substitute the following paragraph for the paragraph starting at page 40, line 10 and ending at line 18.

Further, the shape of each of the reflecting surfaces has different radii of curvature in the orthogonal two planes (yz plane and xz plane). This is for the purpose of suppressing the decentering aberrations produced by the decentering arrangement of each reflecting surface. Further, this reflecting surface is made asymmetric, thereby well correcting various aberrations. A desired optical [performed] <u>performance</u> is thus achieved.

Please substitute the following paragraph for the paragraph starting at page 43, line 12 and ending at page 44, line 3.

In Fig. 5, an optical element 10 has a plurality of curved reflecting surfaces and is made from a glass or like transparent body. The external surface of the optical element 10 is made [up], as comprising, in order of passage of light from an object, a refracting surface R2 (entrance surface) having a negative refractive power in concave form toward the object side, five reflecting surfaces, namely, a concave mirror R3 for giving convergence to the light rays, a convex mirror R4 for giving divergence, a concave mirror R5 for giving convergence, a reflecting surface R6 for giving convergence and a concave mirror R7, and a refracting surface R8 (exit surface) having a positive refractive power in convex form toward the image side. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 45, line 2 and ending at line 12.

In the present embodiment, focusing to a close object is performed by moving the whole optical system relative to the image receiving surface R10 of the image pickup element. Particularly in the present embodiment, because the direction of the reference axis entering the optical element 10 and the direction of the reference axis exiting from the optical element 10 are parallel, the whole optical system can be moved in parallel to the direction of the exiting

reference axis (Z axis direction), so that the focusing operation is carried out [likewise] as in the conventional lens system.

Please substitute the following paragraph for the paragraph starting at page 45, line 17 and ending at line 22.

Besides these, in the present embodiment, because the entrance and exit surfaces for the optical element 10 are arranged on one side thereof, it is possible to make [up] an optical system of reduced width in the X direction with the total length in the direction of the Z axis (+) being minimized.

Please substitute the following paragraph for the paragraph starting at page 48, line 11 and ending at line 26.

In Fig. 7, an optical element 10 has a plurality of curved reflecting surfaces and is made from a glass or like transparent body. The external surface of the optical element 10 is [made up, as comprising] <u>made</u>, in order of passage of light from an object <u>of</u>, a convex refracting surface R2 (entrance surface) having a positive refractive power, six reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5, a reflecting surface R6, a concave mirror R7 and a convex mirror R8, and a convex refracting surface R9 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R10 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 52, line 4 and ending at line 19.

In Fig. 9, an optical element 10 has a plurality of curved reflecting surfaces and is made from [a] glass or like transparent body. The external surface of the optical element 10 is [made up, as comprising] made, in order of passage of light from an object of, a concave refracting surface R2 (entrance surface) having a negative refractive power, four reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5 and a reflecting surface R6, and a convex refracting surface R7 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 54, line 10 and ending at line 27.

As far as the present embodiment is concerned, there are two ways of tilting each surface, one of which is in the XZ plane and the other in the XY plane. Accordingly, the local coordinate system should otherwise be defined. The angle to which the i-th surface is first tilted in the XZ plane is expressed by ϕi (in units of degree) with the clockwise direction as viewed from the plus direction of the Y axis being taken as positive, and then in the XY plane by θi (in units of degree) with the counterclockwise direction as viewed from the plus direction of the Z axis being taken as positive. For the axes of the local coordinates (x,y,z) for the i-th surface to define in relation to the absolute coordinate system (X,Y,Z), suppose the local coordinate system is first moved

[till] <u>until</u> its original point coincides with a point (Xi,Yi,Zi), then turned in the XZ plane to the angle ϕi and, at last, turned in the XY plane to the angle θi, the following settings are thus obtained:

Please substitute the following paragraph for the paragraph starting at page 57, line 7 and ending at line 23.

In Figs. 11A and 11B, an optical element 10 has a plurality of curved reflecting surfaces and is made from [a] glass or like transparent body. The external surface of the optical element 10 is made [up], as [comprising], in order of passage of light from an object <u>of</u>, a convex refracting surface R2 (entrance surface) having a positive refractive power, six reflecting surfaces, namely, a flat reflecting plane R3, a concave mirror R4, a convex mirror R5, a concave mirror R6, a reflecting surface R7 and a concave mirror R8, and a convex refracting surface R7 (exit surface) having a positive refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 58, line 25 and ending at page 59, line 3. A marked-up copy of this paragraph, showing the changes made thereto is attached.

In the case of the present embodiment, the entrance surface R2 of the optical element 10 is made to have a relatively strong positive refractive power, thereby condensing the on-axial and

off-axial light beams. The flat reflecting surface R3 is thus prevented from increasing in the size. This [leads to achieve] <u>achieves</u> a further thinning of the whole optical system.

Please substitute the following paragraph for the paragraph starting at page 59, line 10 and ending at line 25.

In the preceding embodiments, [the whole] <u>all of the</u> reference axes, including the entering reference axis, and the exiting reference axis are contained in a certain plane (YZ plane). From the point of view of the layout of the photographic optical system, it is desirable in some cases that the entering reference axis is not in parallel with that plane. So, in the case of the present embodiment, the thinning is possible in the perpendicular direction (in this instance, the Z axis direction) to the plane in which the zigzagged reference axis of the interior of the optical system is contained likewise as in the other embodiments. Because of this, a photographic optical system of reduced thickness in the shooting direction can be formed. So, the degree of freedom for incorporating the optical system into the camera or the like is further increased.

Please substitute the following paragraph for the paragraph starting at page 62, line 16 and ending at page 63, line 2.

In Fig. 14, a block 60 of hollow core (optical element) has a plurality of curved reflecting surfaces formed in the interior thereof. The internal surface of the optical element 60 is made [up, as comprising], in order of passage of light from an object <u>of</u>, four reflecting surfaces, namely, a concave mirror R2, reflecting surfaces R3 and R4 and a concave mirror R5. A stop R1 (entrance pupil) is located on the object side of the optical element 60. A last image plane R6 is

coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 66, line 11 and ending at line 26.

In Fig. 16, a block 60 of hollow core (optical element) has a plurality of curved reflecting surfaces formed in the interior thereof. Two positive lenses 71 and 72 (refracting optical systems) are located at the entrance and exit of the optical element 60, respectively. The internal surface of the optical element 60 is made [up, as comprising], in order of passage of light from an object <u>of</u>, four reflecting surfaces, namely, a concave mirror R4, a convex mirror R5, a concave mirror R6 and a reflecting surface R7. A stop R1 (entrance pupil) is located on the object side of the positive lens 71. A last image plane R10 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 67, line 21 and ending at line 27.

Owing to such refractive powers in the interior of the optical element 60 by the plurality of curved reflecting mirrors, and to such refractive powers by the two positive lenses 71 and [71]

72, the optical system 70 functions as a lens unit having a desired optical performance with the overall refractive power being positive.

Please substitute the following paragraph for the paragraph starting at page 70, line 18 and ending at page 71, line 8.

In Fig. 18, an optical element 10 has two refracting surfaces and a plurality of curved reflecting surfaces and is made from [a] glass or like transparent body. The external surface of the optical element 10 is made [up, as comprising], in order of passage of light from an object of, a concave refracting surface R2 (entrance surface) having a negative refractive power, four reflecting surfaces, namely, a concave mirror R3, a reflecting surface R4, a reflecting surface R5 and a concave mirror R6, and a concave refracting surface R7 (exit surface) having a negative refractive power. A stop R1 (entrance pupil) is located on the object side of the optical element 10. A last image plane R8 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5. The whole of the reference axis lies in the paper of the drawing (YZ plane).

Please substitute the following paragraph for the paragraph starting at page 72, line 18 and ending at line 24.

Fig. 20 is a sectional view in the YZ plane of a ninth embodiment of the optical system according to the invention . The present embodiment is a photographic optical system of 63.4 degrees in the horizontal angle of view and 49.6 degrees in the vertical angle of view. Fig. 20

[even] also shows the optical path. The data of the design parameters of the present embodiment are as follows:

Please substitute the following paragraph for the paragraph starting at page 74, line 18 and ending at page 75, line 6.

In Fig. 20, an optical element 10 has a plurality of curved reflecting surfaces and is made from [a] glass or like transparent body. The external surface of the optical element 10 is made [up, as comprising], in order of passage of light from an object of, a convex refracting surface R2 (entrance surface) having a positive refractive power, five reflecting surfaces, namely, a concave mirror R3, a convex mirror R4, a concave mirror R5, a reflecting surface R6 and a concave mirror R7, and a convex refracting surface R8 (exit surface) having a positive refractive power. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 76, line 21 and ending at page 77, line 3.

In the present embodiment, the entrance surface R2 is made to be a convex refracting surface of sphere, thereby converging the off-axial principal ray. With this, when [to increase] increasing the angle of field, the size of the first reflecting surface R3 is prevented from becoming big. The exit surface R8, too, is made to be a convex refracting surface of sphere, thereby preventing the back focal distance from increasing [unduly largely] too much. At the

same time, the off-axial rays are controlled so that the off-axial principal ray becomes telecentric to the image side.

Please substitute the following paragraph for the paragraph starting at page 77, line 5 and ending at line 11.

Fig. 22 is a sectional view in the YZ plane of a tenth embodiment of the optical system according to the invention. The present embodiment is a photographic optical system of 63.4 degrees in the horizontal angle of view and 49.6 degrees in the vertical angle of view. In Fig. 22, the optical path is [even] <u>also</u> shown. The data of the design parameters of the present embodiment are as follows:

Please substitute the following paragraph for the paragraph starting at page 79, line 6 and ending at line 20.

In Fig. 22, an optical element 10 has a plurality of curved reflecting surfaces and is made from [a] glass or like transparent body. The external surface of the optical element 10 is made [up, as comprising], in order of passage of light from an object <u>of</u>, a convex refracting surface R2 (entrance surface) having a positive refractive power, five reflecting surfaces, namely, a concave mirror R3, reflecting surfaces R4, R5 and R6 and a concave mirror R7, and a concave refracting surface R8 (exit surface) having a negative refractive power. A stop R1 is located on the object side of the optical element 10. A last image plane R9 is coincident with the image sensing surface of a CCD or like image pickup element. A reference axis of the photographic optical system is indicated by reference numeral 5.

Please substitute the following paragraph for the paragraph starting at page 81, line 9 and ending at line 19.

In the present embodiment, the entrance surface R2 is made to be a convex refracting surface of a sphere, thereby converging the off-axial principal ray. With this, when [to increase] <u>increasing</u> the angle of field, the effective diameter of the first reflecting surface R3 is prevented from increasing in [its] size. Also, the exit surface R8 is made to be a concave refracting surface of sphere. With this[, an] arrangement [is resulted that,] for the on-axial rays, a long back focal distance is secured, and [that,] for the off-axial rays, it becomes telecentric to the image side.

Please substitute the following paragraph for the paragraph starting at page 84, line 9 and ending at line 18.

With the use of the optical elements each having a plurality of reflecting surfaces of curved and flat shapes formed in unison, the compact form of the entirety of the mirror optical system is improved, while still permitting the position and angle tolerances (assembling tolerances) for the reflecting mirrors to be made looser than was heretofore usually necessary to the mirror optical systems. Hence, it is possible to achieve a [high] <u>highly</u> accurate optical system of reflecting type and an image pickup apparatus using the same.

Please substitute the following paragraph for the paragraph starting at page 85, line 10 and ending at line 25.

In the case of the embodiments either when the stop is ahead of the optical element, or when the entrance pupil lies on the object side of the first reflecting surface, when counted from

the object side[,] of the optical element, particularly the impartment of the converging function to the first reflecting surface of the optical element contributes to a reduction of the size of the optical system, since the pupil ray (principal ray) forms the intermediate image in the stage near to the entrance surface, so that a further thinning of the optical system is assured. After having exited from the stop R1 and before diverging largely, the off-axial principal ray is made to converge. With this, when [to increase] <u>increasing</u> the angle of view of the optical system, the increase of the effective diameters of the first reflecting surface and those that follow is suppressed.

Please substitute the following paragraph for the paragraph starting at page 87, line 10 and ending at line 18.

Further, in the embodiments, whilst almost every reflecting surfaces has only one plane of symmetry, the entrance and exit surfaces are of rotationally symmetric form with respect to the reference axis. By virtue of this, the reference axis can be accurately measured and tested when [to manufacture] <u>manufacturing</u> the optical systems. Also, by making the refracting surface to be rotationally symmetric, the amount of produced asymmetric chromatic aberrations can be reduced.

Please substitute the following paragraph for the paragraph starting at page 88, line 20 and ending at page 89, line 2.

The reflecting surfaces constituting the optical element each have its normal line at the point of intersection of the entering and exiting reference axis to be out of coincidence with the

direction of the reference axis, or are the so-called decentered reflecting surface. This is for the purpose of preventing the vignetting effect from being produced as in the conventional mirror optical system. At the same time, by this, a free layout can be [permitted to adopt] adopted. So, an optical element of good space efficiency, compact form and free shape can be made up.

Please substitute the following paragraph for the paragraph starting at page 90, line 24 and ending at page 91, line 3.

In more detail, according to the invention, a wide variety of forms of optical elements can be obtained with the orientation of the entering reference axis different from that of the exiting reference axis. By virtue of a high degree of freedom for the layout, therefore, it becomes possible to adopt the most suitable form of the photographic optical system [to] for the camera or the like apparatus.

FIG. 4

Y DIRECTION X DIRECTION

FIG. 4A

VERTICAL ANGLE OF INCIDENCE U_X 20.3
U_Y 26.3 HORIZONTAL ANGLE OF INCIDENCE

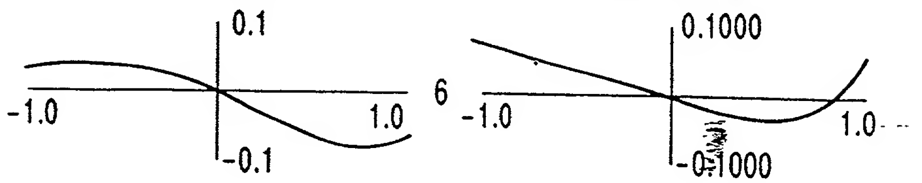


FIG. 4B

VERTICAL ANGLE OF INCIDENCE U_X 20.3
U_Y 0 HORIZONTAL ANGLE OF INCIDENCE

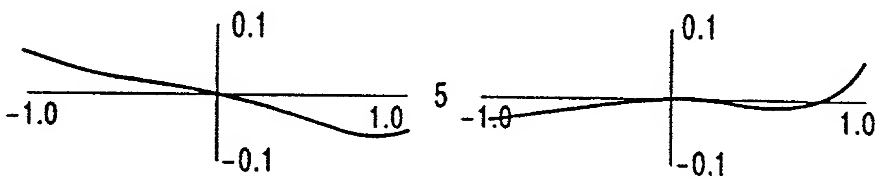


FIG. 4C

VERTICAL ANGLE OF INCIDENCE U_X 20.3
U_Y -26.3 HORIZONTAL ANGLE OF INCIDENCE

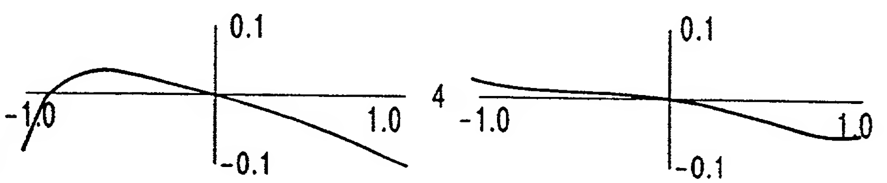


FIG. 4D

VERTICAL ANGLE OF INCIDENCE U_X 0
U_Y 26.3 HORIZONTAL ANGLE OF INCIDENCE

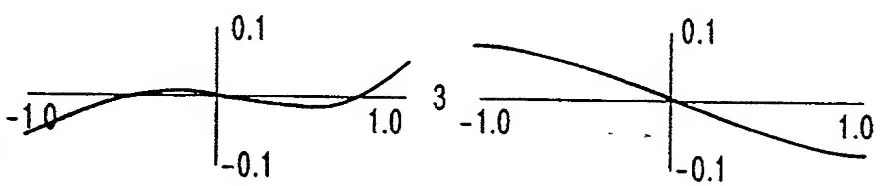


FIG. 4E

VERTICAL ANGLE OF INCIDENCE U_X 0
U_Y 0 HORIZONTAL ANGLE OF INCIDENCE

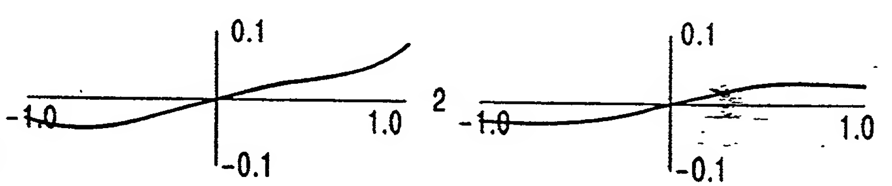


FIG. 4F

VERTICAL ANGLE OF INCIDENCE U_X 0
U_Y -26.3 HORIZONTAL ANGLE OF INCIDENCE

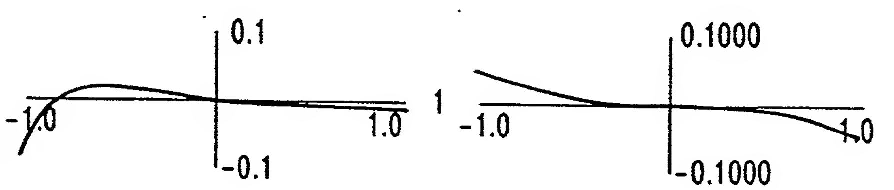


FIG. 6

Y DIRECTION X DIRECTION

FIG. 6A

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE

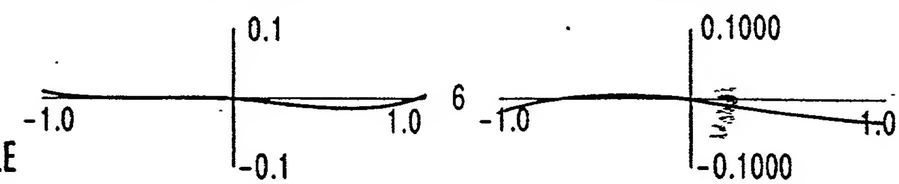


FIG. 6B

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

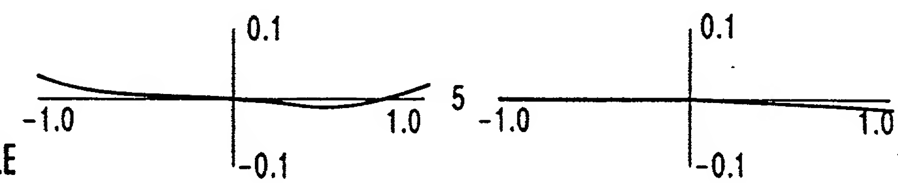


FIG. 6C

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE

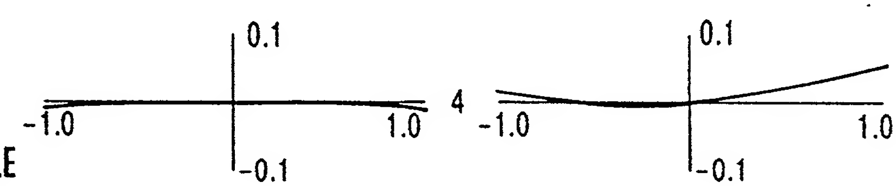


FIG. 6D

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE

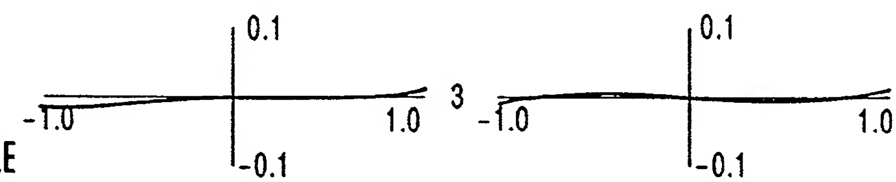


FIG. 6E

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

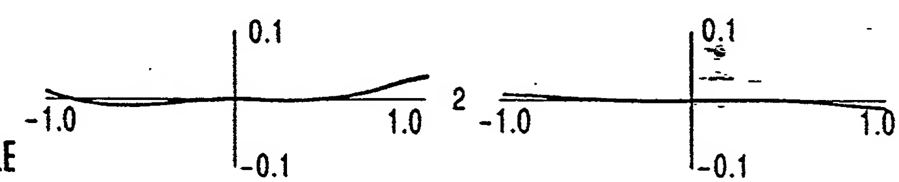


FIG. 6F

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE

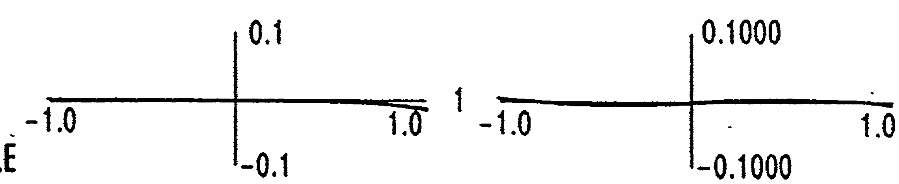


FIG. 8

Y DIRECTION | X DIRECTION

FIG. 8A

VERTICAL ANGLE OF INCIDENCE
U_X 26.0
U_Y 20.0
HORIZONTAL ANGLE OF INCIDENCE

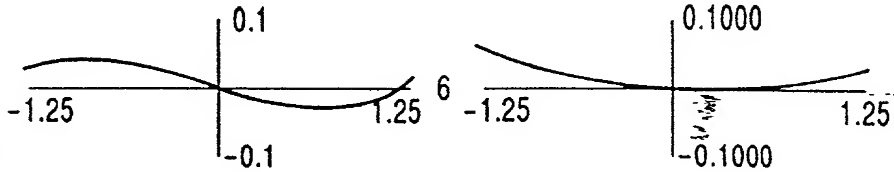


FIG. 8B

VERTICAL ANGLE OF INCIDENCE
U_X 26.0
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

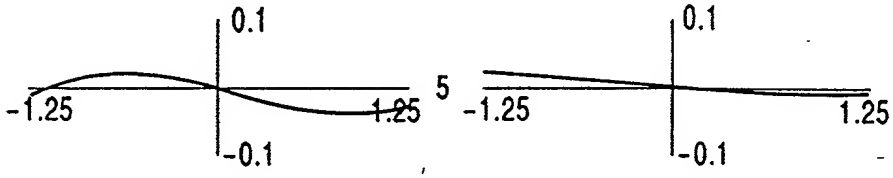


FIG. 8C

VERTICAL ANGLE OF INCIDENCE
U_X 26.0
U_Y -20.0
HORIZONTAL ANGLE OF INCIDENCE

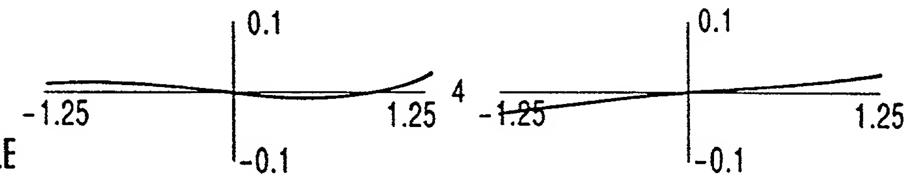


FIG. 8D

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 20.0
HORIZONTAL ANGLE OF INCIDENCE

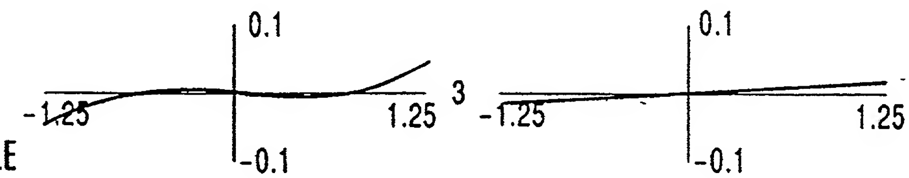


FIG. 8E

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

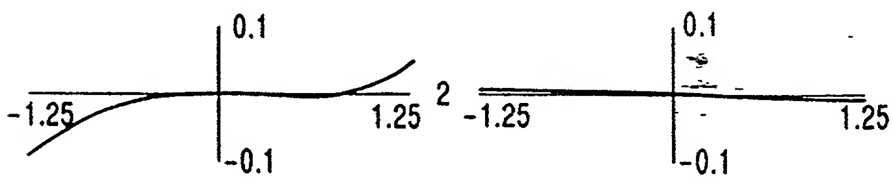


FIG. 8F

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y -20.0
HORIZONTAL ANGLE OF INCIDENCE

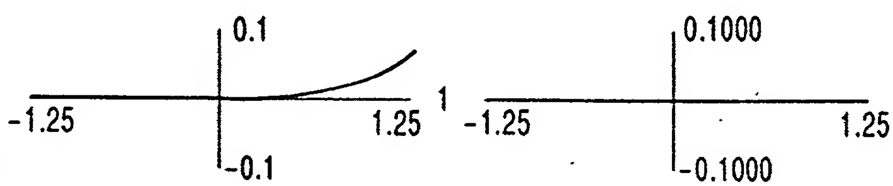


FIG. 10

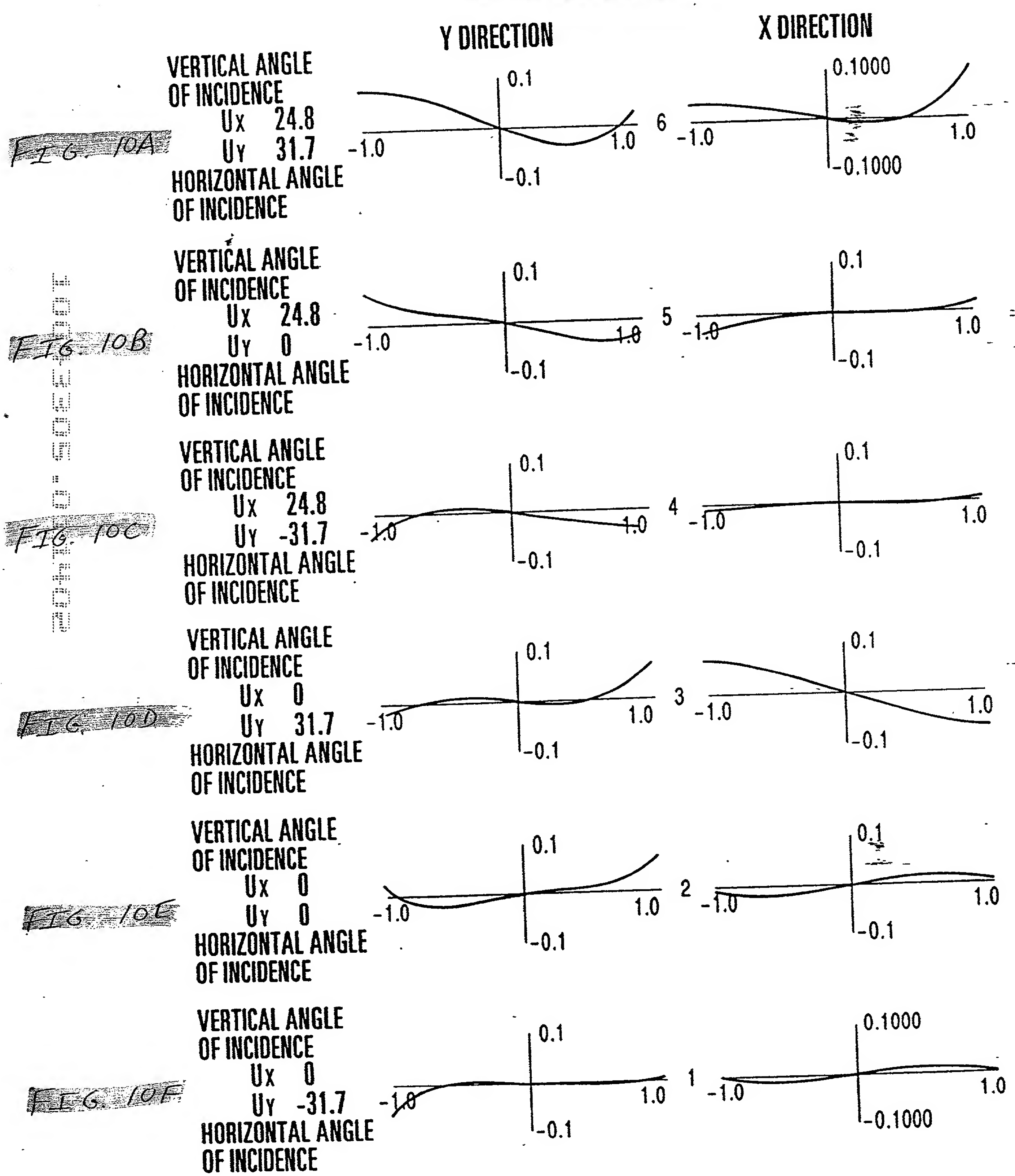

Y DIRECTION
X DIRECTION
FIG. 10A
VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE
0.1
-0.1
-1.0
1.0
6
0.1000
-0.1000
FIG. 10B
VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 0
HORIZONTAL ANGLE OF INCIDENCE
5
FIG. 10C
VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE
4
FIG. 10D
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE
3
FIG. 10E
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE
2
FIG. 10F
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE
1

FIG. 13

Y DIRECTION | X DIRECTION

FIG. 13A

VERTICAL ANGLE OF INCIDENCE
Ux 22.0
Uy 28.4
HORIZONTAL ANGLE OF INCIDENCE

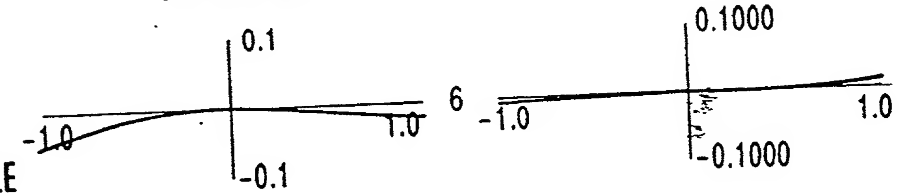


FIG. 13B

VERTICAL ANGLE OF INCIDENCE
Ux 22.0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

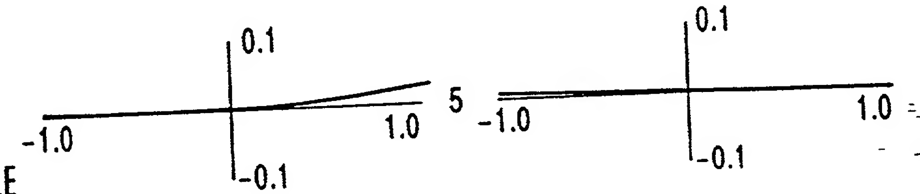


FIG. 13C

VERTICAL ANGLE OF INCIDENCE
Ux 22.0
Uy -28.4
HORIZONTAL ANGLE OF INCIDENCE

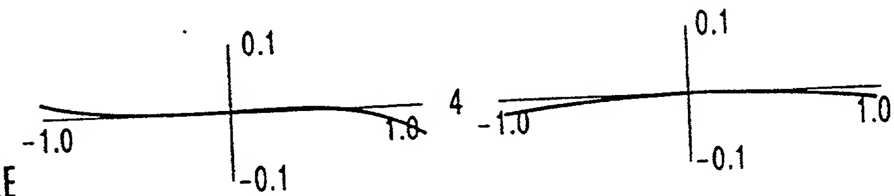


FIG. 13D

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 28.4
HORIZONTAL ANGLE OF INCIDENCE

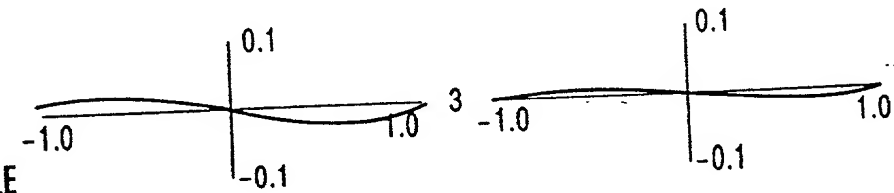


FIG. 13E

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

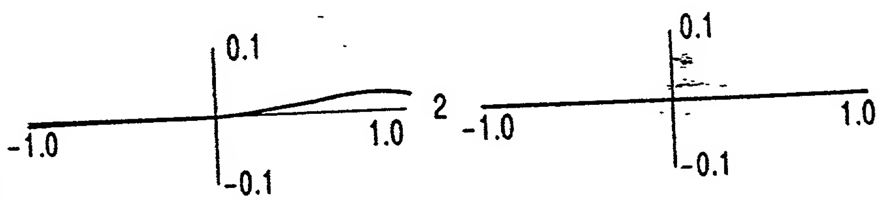


FIG. 13F

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -28.4
HORIZONTAL ANGLE OF INCIDENCE

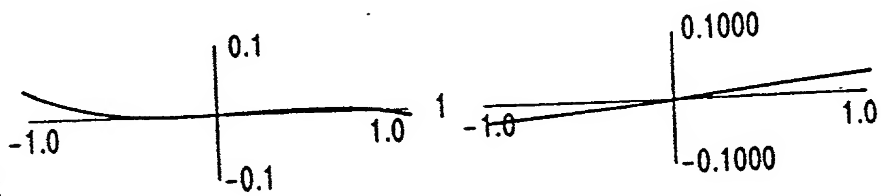


FIG. 15

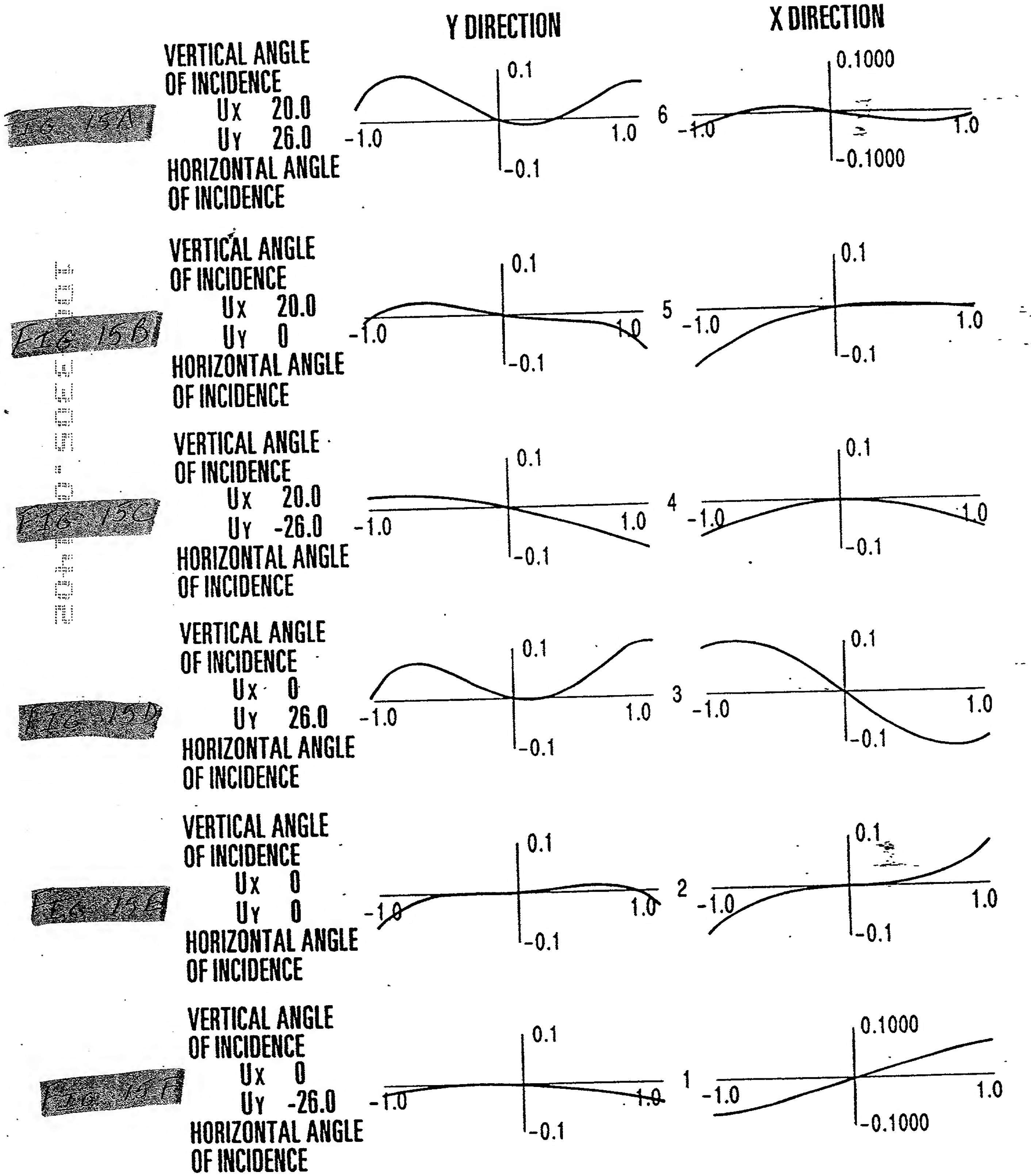


FIG. 15A
FIG. 15B
FIG. 15C
FIG. 15D
FIG. 15E
FIG. 15F
Y DIRECTION
X DIRECTION
VERTICAL ANGLE OF INCIDENCE
Ux 20.0
Uy 26.0
HORIZONTAL ANGLE OF INCIDENCE
0.1
-0.1
-1.0
1.0
6
0.1000
-0.1000
VERTICAL ANGLE OF INCIDENCE
Ux 20.0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE
5
VERTICAL ANGLE OF INCIDENCE
Ux 20.0
Uy -26.0
HORIZONTAL ANGLE OF INCIDENCE
4
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 26.0
HORIZONTAL ANGLE OF INCIDENCE
3
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE
2
VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -26.0
HORIZONTAL ANGLE OF INCIDENCE
1

FIG. 17

FIG 17A

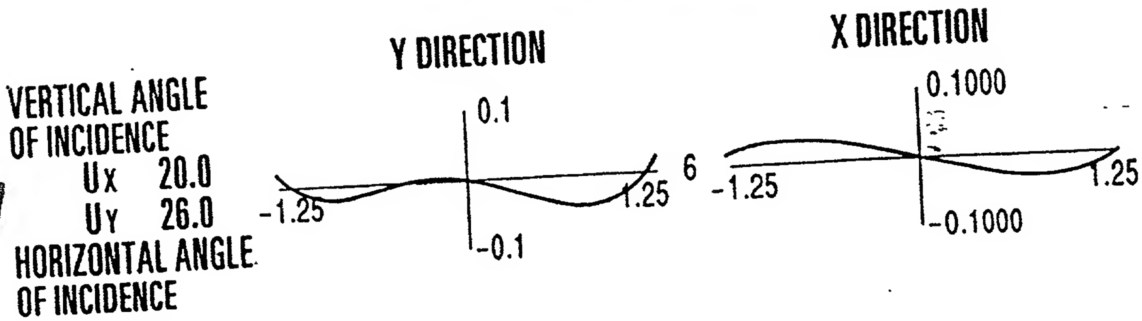


FIG 17B

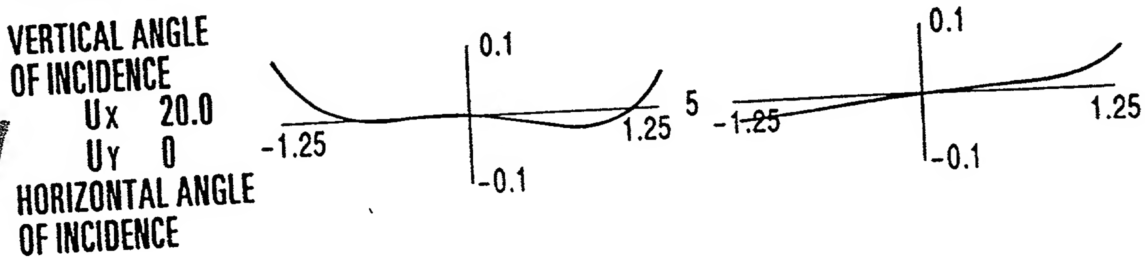


FIG 17C

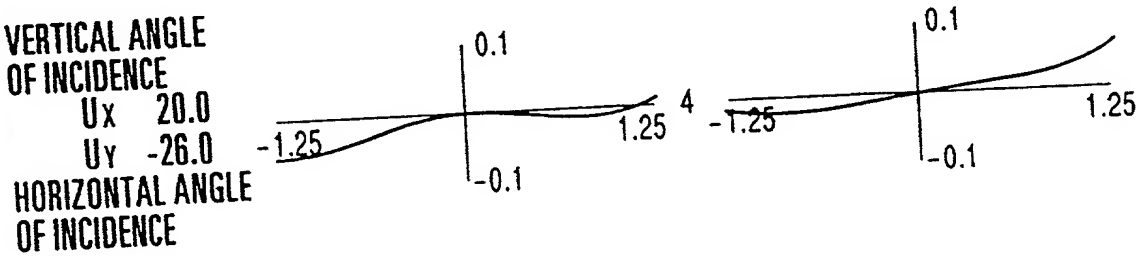


FIG 17D

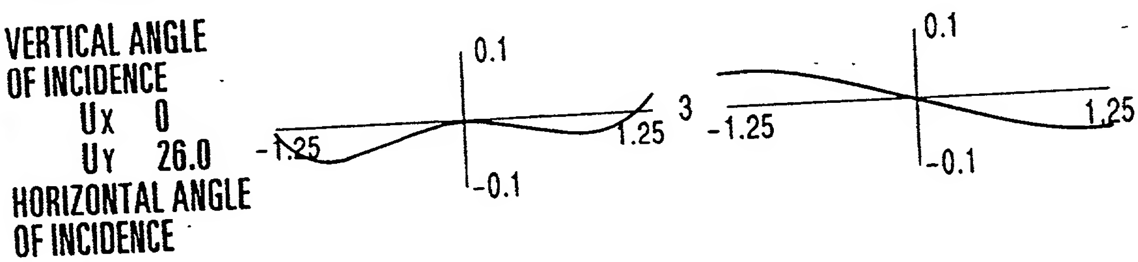


FIG 17E

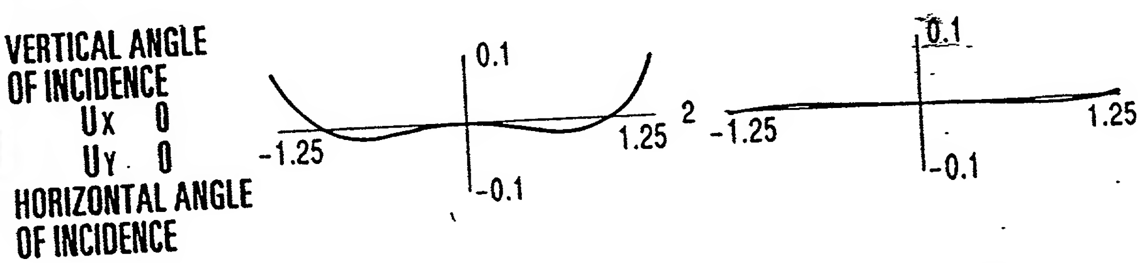


FIG 17F

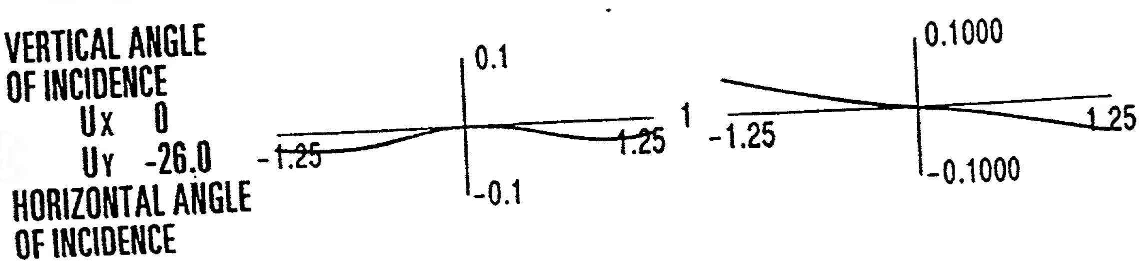


FIG. 19

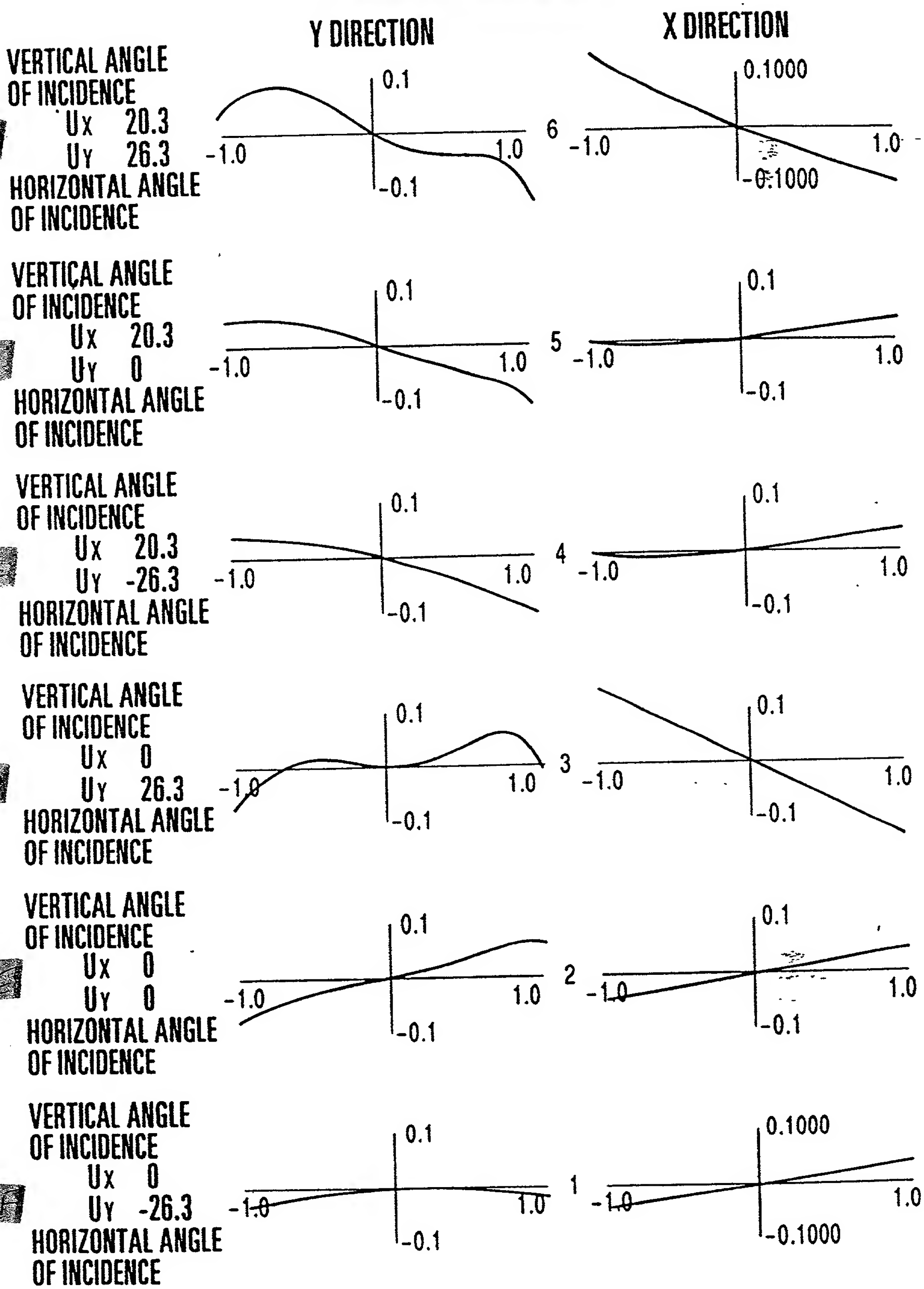


FIG. 19A

FIG. 19B

FIG. 19C

FIG. 19D

FIG. 19E

FIG. 19F

FIG. 21

FIG. 21A

FIG. 21B

FIG. 21C

FIG. 21D

FIG. 21E

FIG. 21F

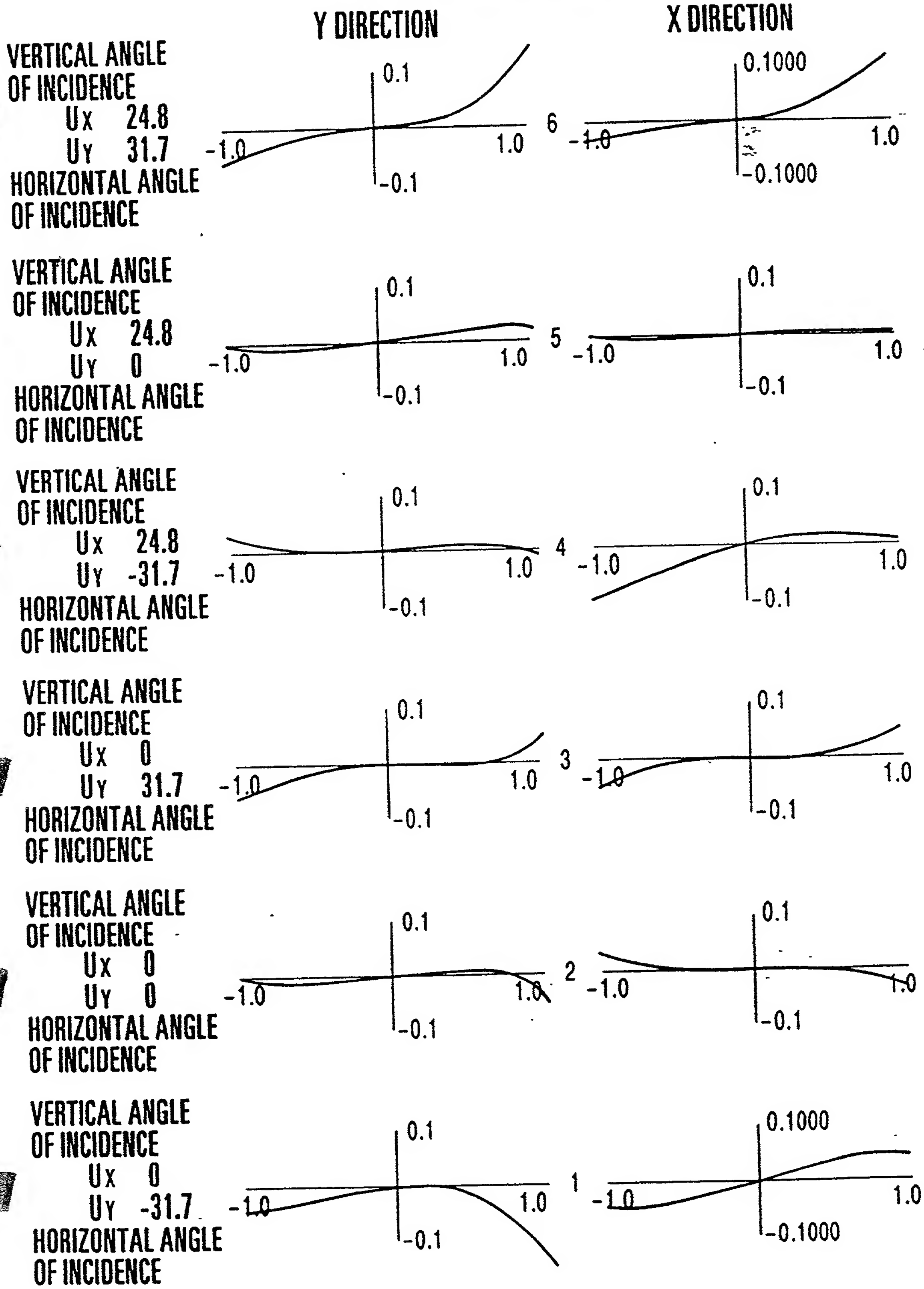


FIG. 23

FIG. 23A

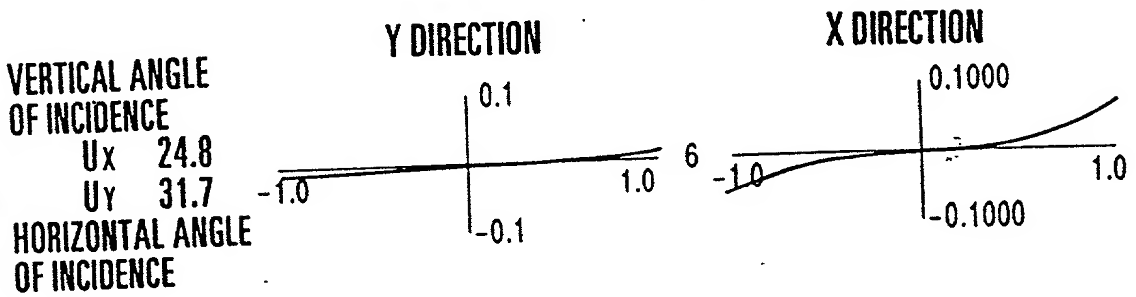


FIG. 23B

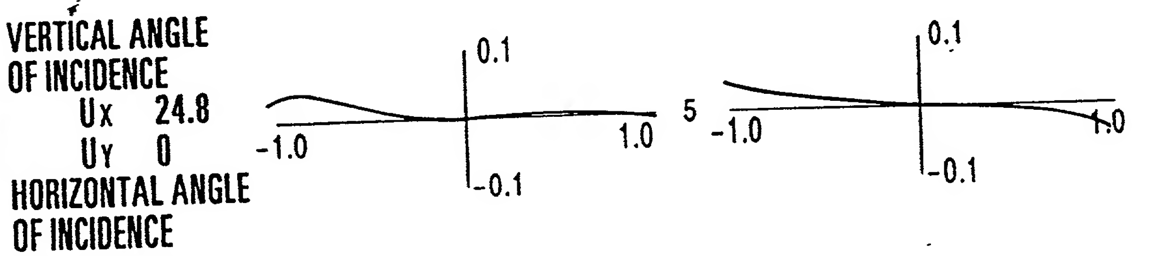


FIG. 23C

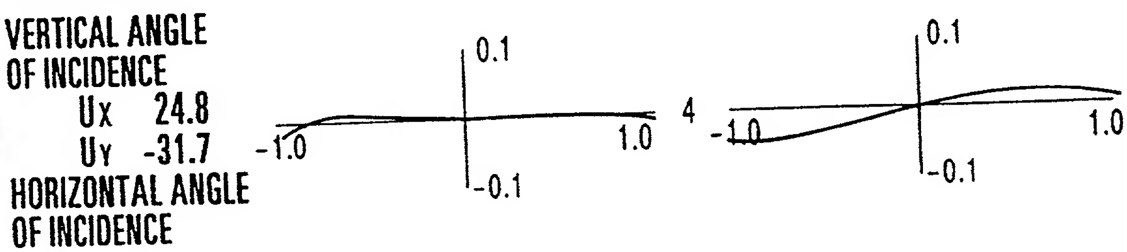


FIG. 23D

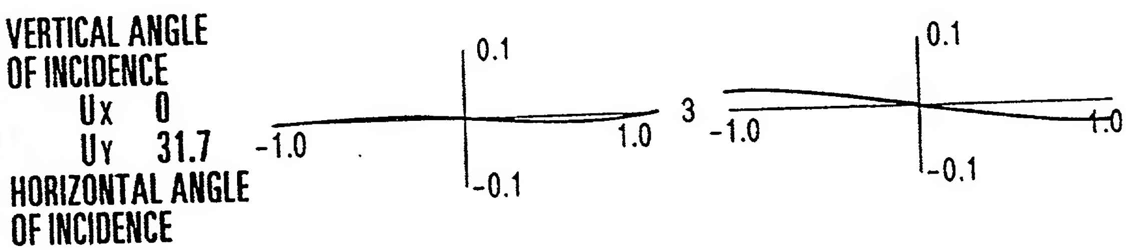


FIG. 23E

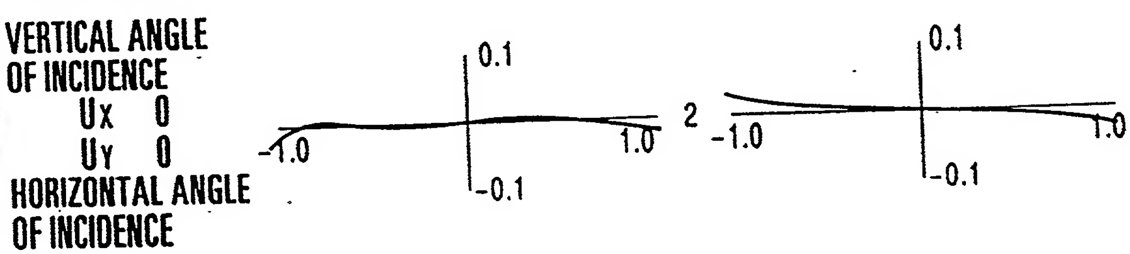
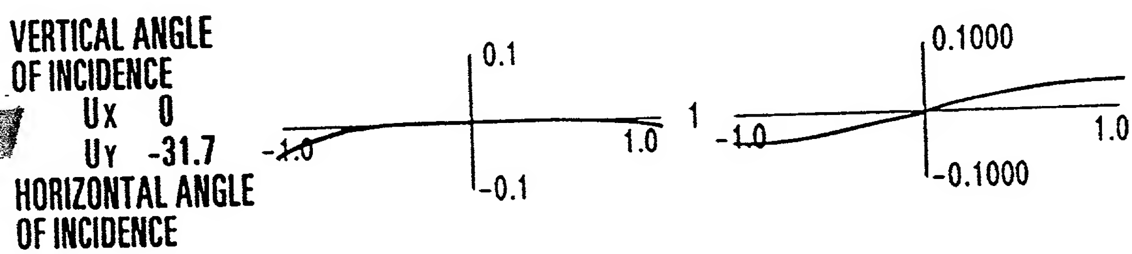


FIG. 23F



Y DIRECTION X DIRECTION

FIG.4A

VERTICAL ANGLE OF INCIDENCE
Ux 20.3
Uy 26.3
HORIZONTAL ANGLE OF INCIDENCE

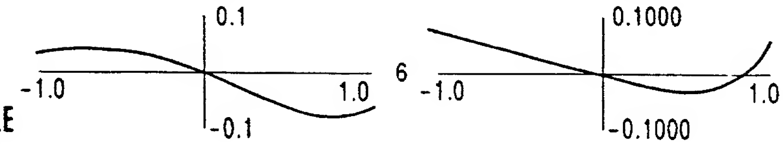


FIG.4B

VERTICAL ANGLE OF INCIDENCE
Ux 20.3
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

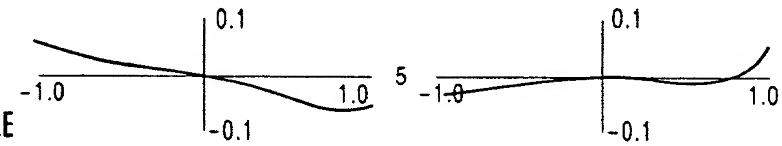


FIG.4C

VERTICAL ANGLE OF INCIDENCE
Ux 20.3
Uy -26.3
HORIZONTAL ANGLE OF INCIDENCE

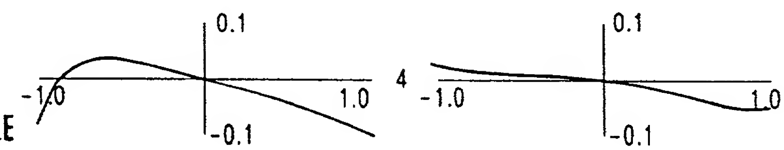


FIG.4D

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 26.3
HORIZONTAL ANGLE OF INCIDENCE

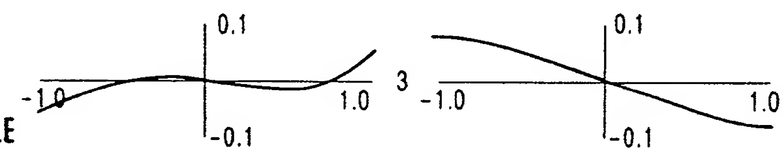


FIG.4E

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

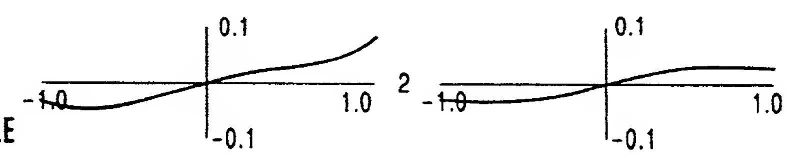


FIG.4F

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -26.3
HORIZONTAL ANGLE OF INCIDENCE

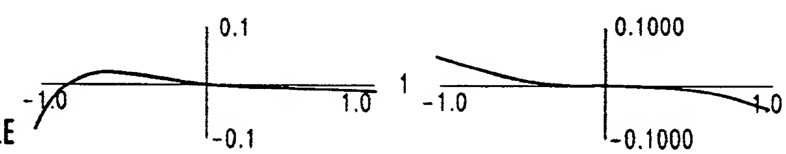


FIG.6A

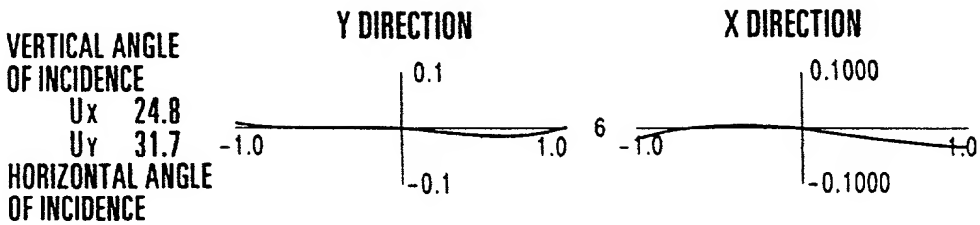


FIG.6B

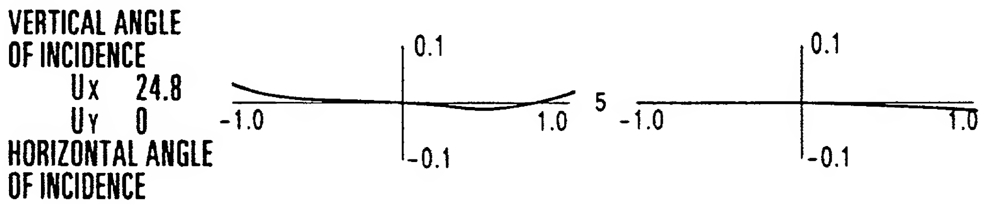


FIG.6C

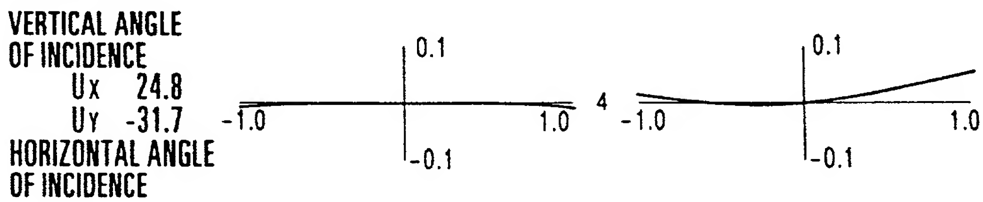


FIG.6D

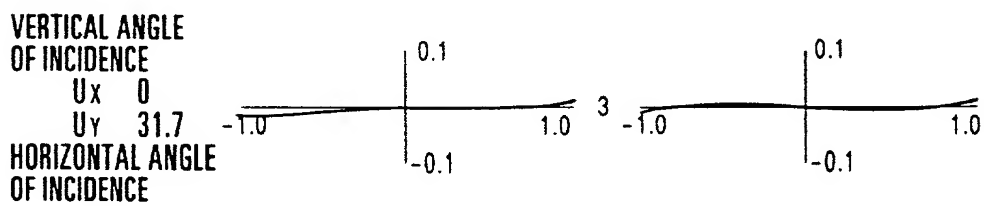


FIG.6E

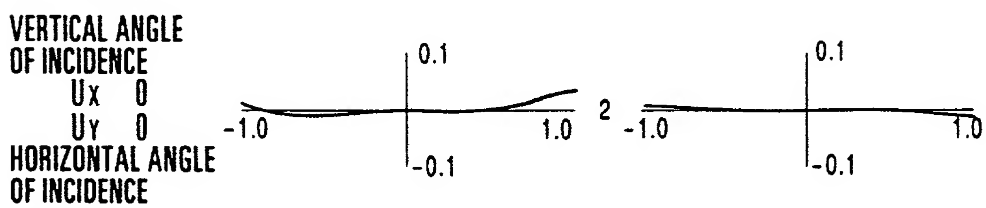


FIG.6F

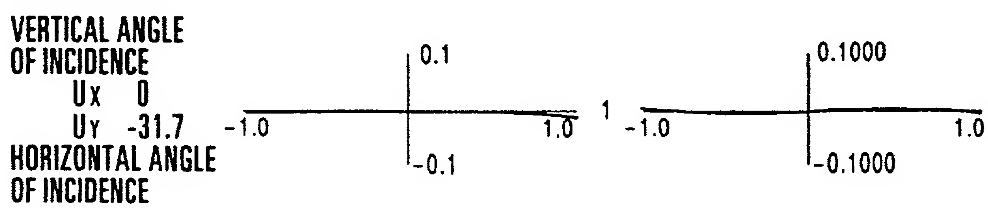


FIG.8A

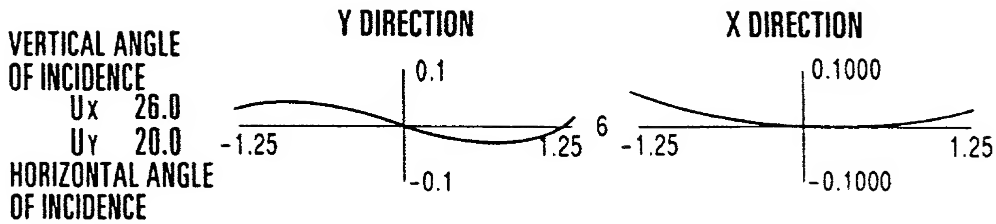


FIG.8B

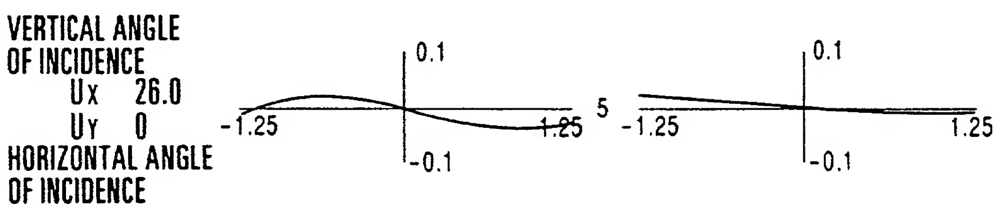


FIG.8C

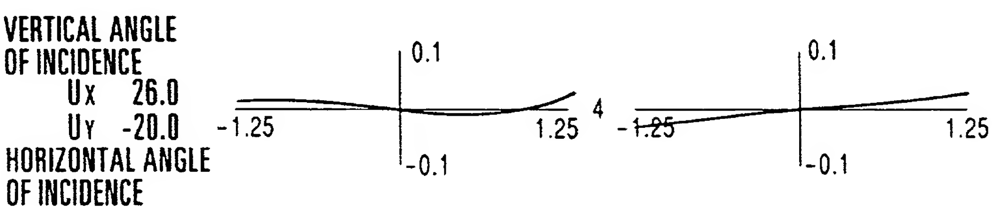


FIG.8D

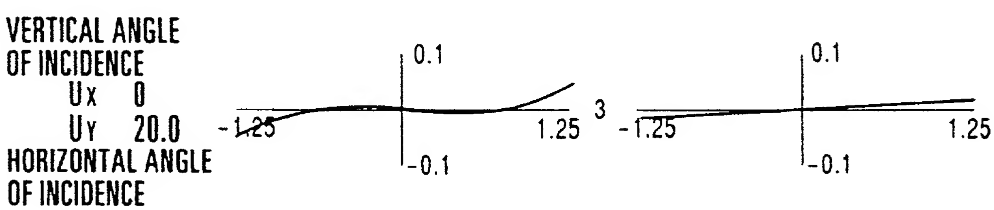


FIG.8E

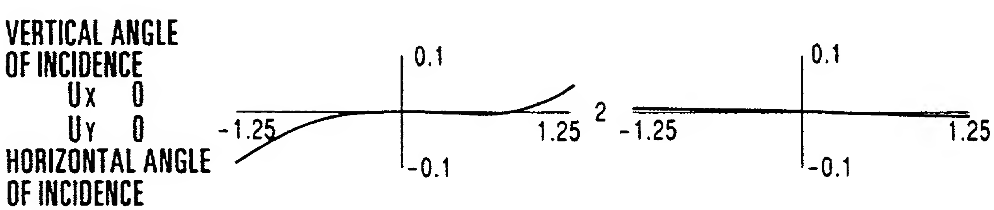
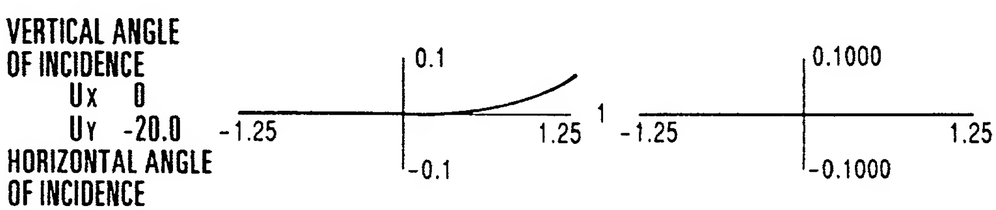


FIG.8F



Y DIRECTION X DIRECTION

FIG.10A

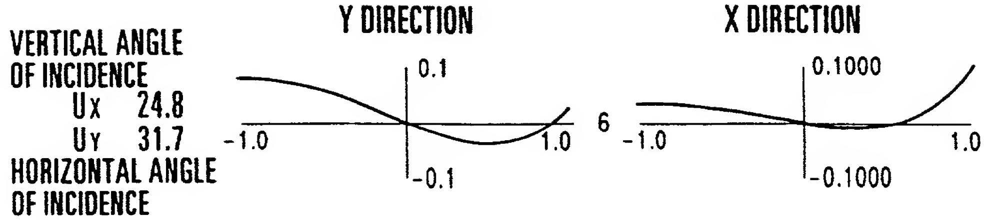


FIG.10B

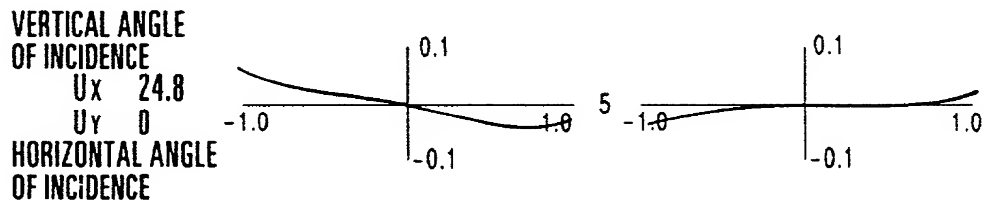


FIG.10C

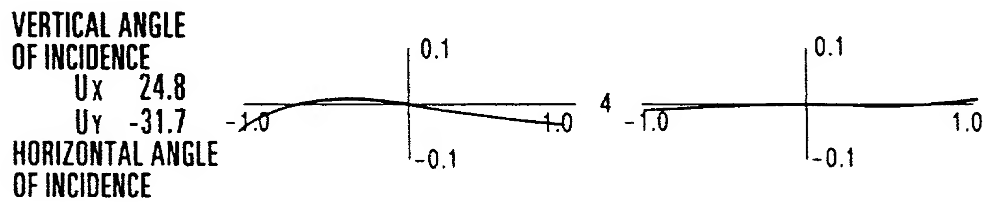


FIG.10D

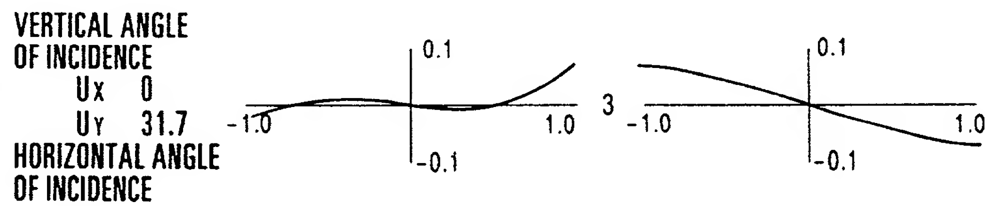


FIG.10E

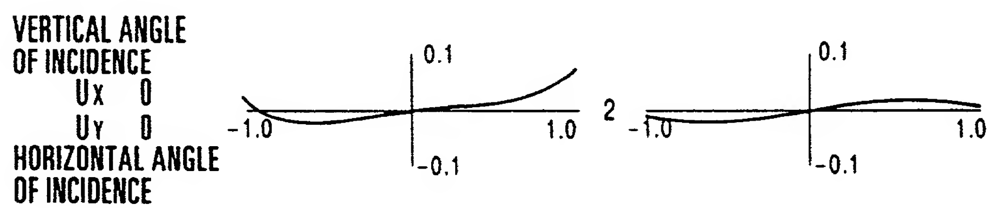
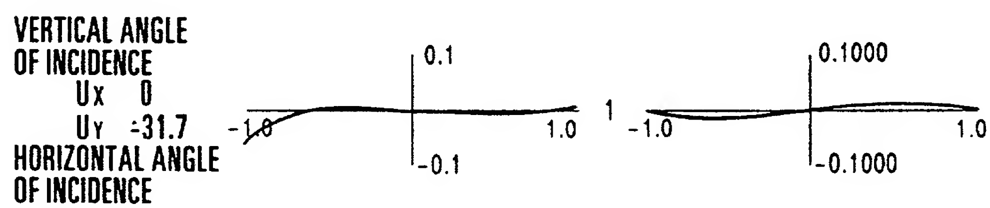


FIG.10F



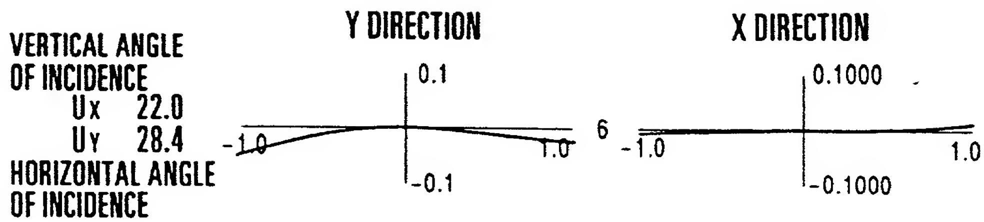


FIG.13A

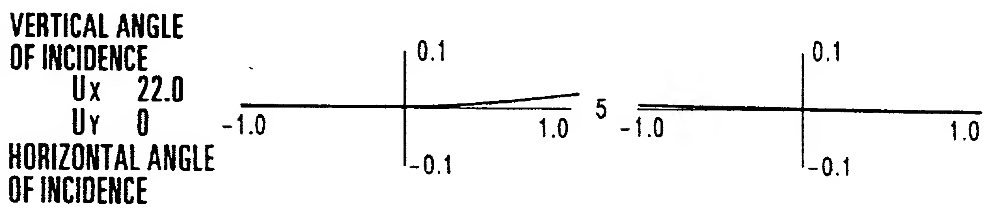


FIG.13B

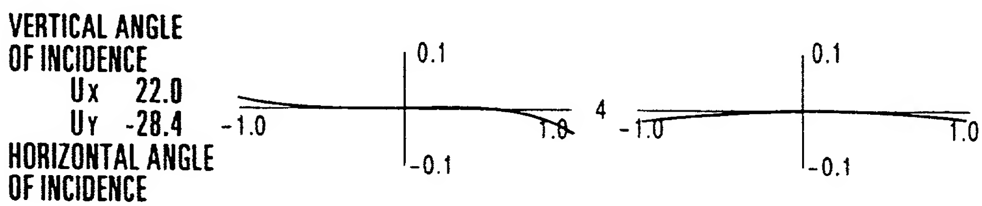


FIG.13C

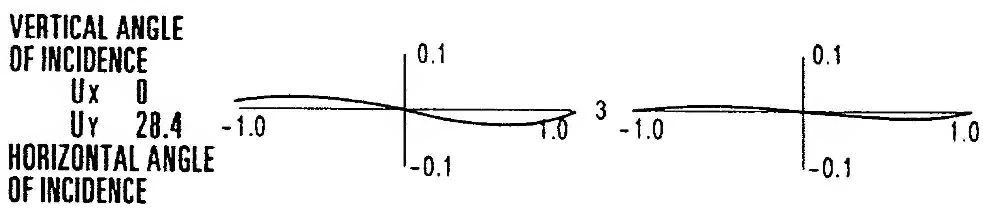


FIG.13D

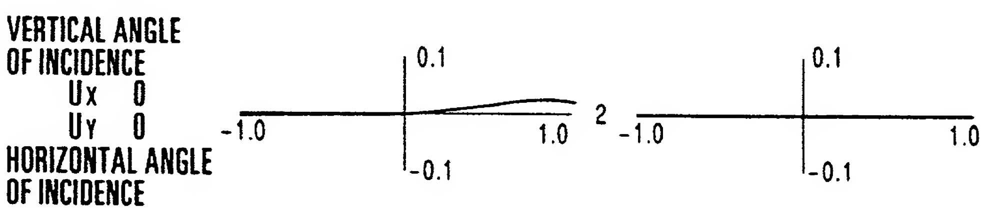


FIG.13E

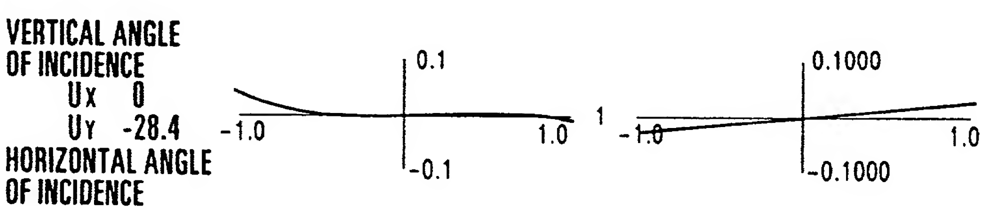


FIG.13F

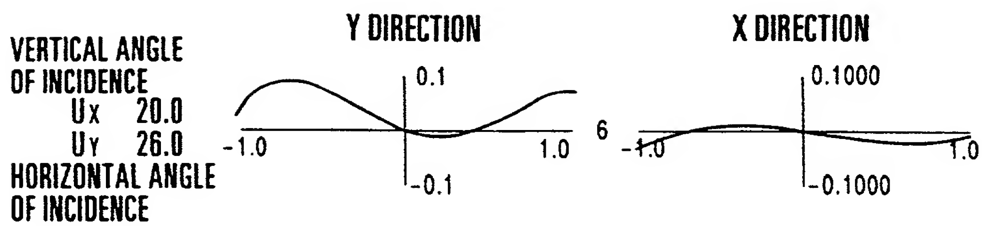


FIG.15A

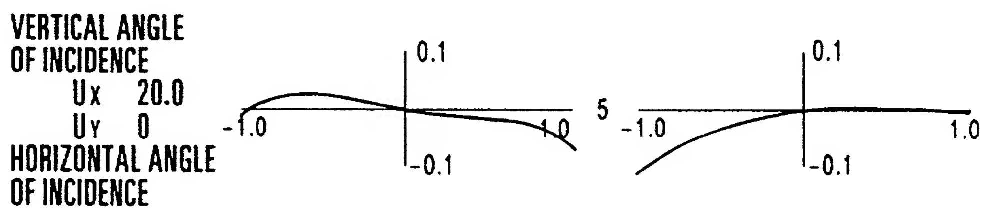


FIG.15B

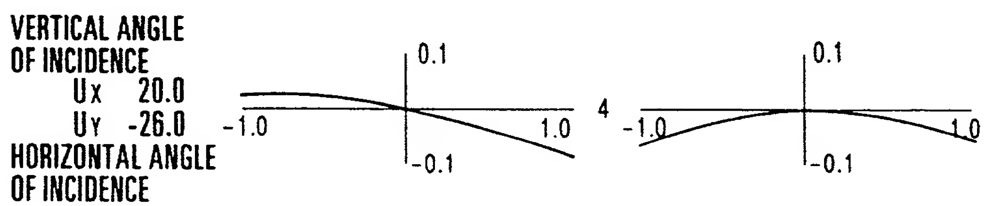


FIG.15C

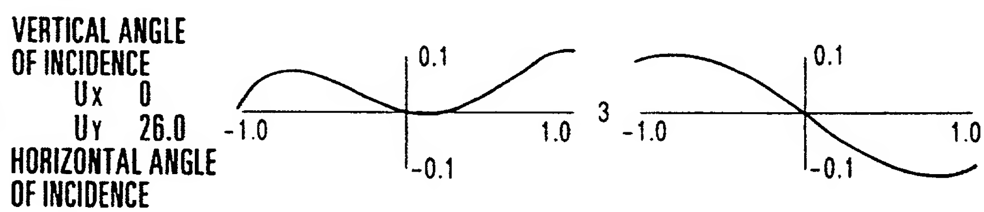


FIG.15D

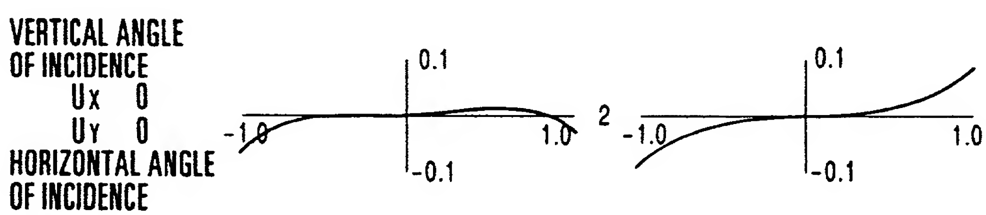


FIG.15E

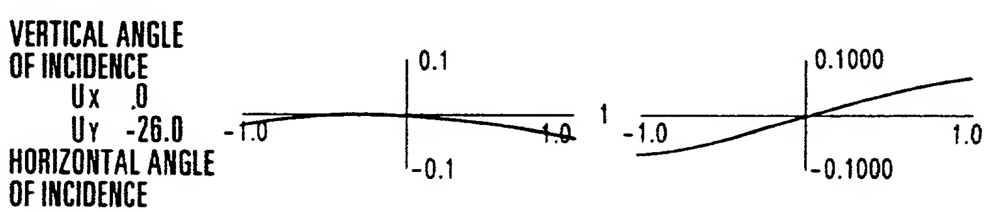


FIG.15F

Y DIRECTION X DIRECTION

FIG.17A

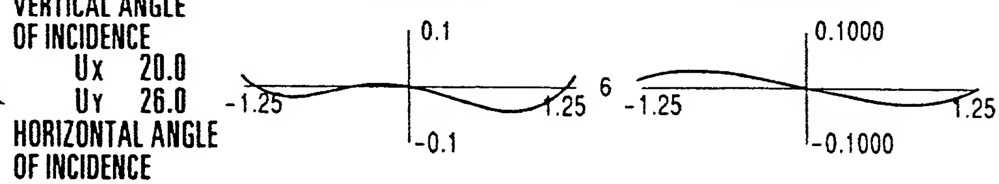


FIG.17B

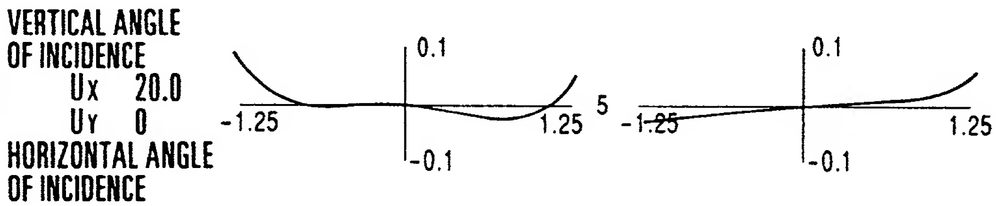


FIG.17C

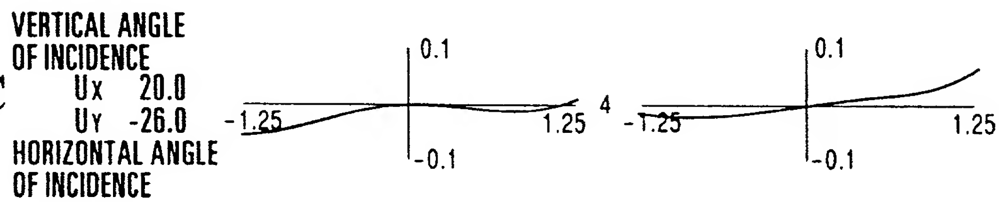


FIG.17D

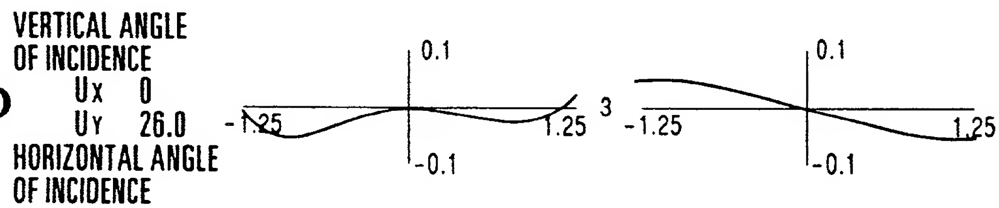


FIG.17E

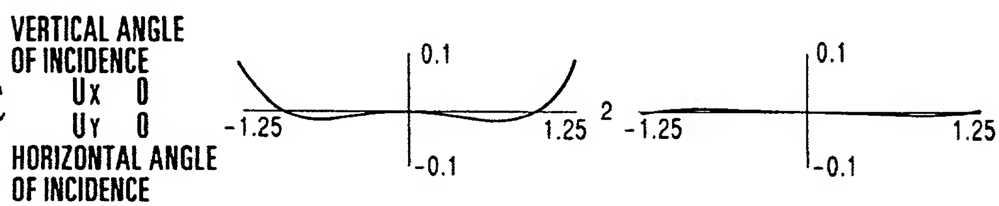
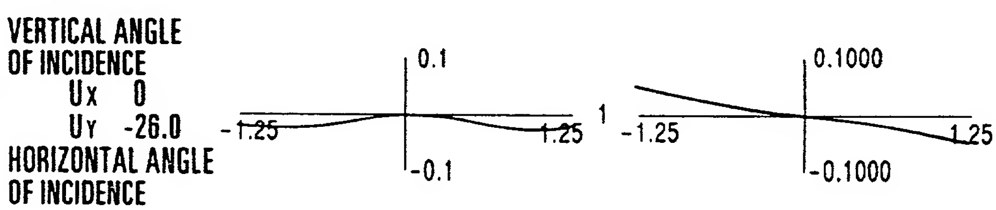


FIG.17F



Y DIRECTION X DIRECTION

FIG.19A

VERTICAL ANGLE OF INCIDENCE
U_X 20.3
U_Y 26.3
HORIZONTAL ANGLE OF INCIDENCE

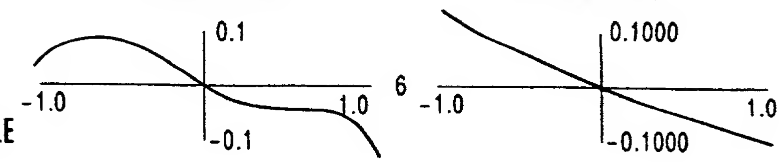


FIG.19B

VERTICAL ANGLE OF INCIDENCE
U_X 20.3
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

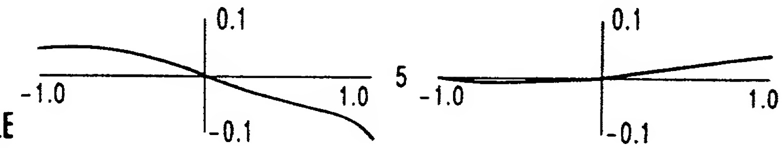


FIG.19C

VERTICAL ANGLE OF INCIDENCE
U_X 20.3
U_Y -26.3
HORIZONTAL ANGLE OF INCIDENCE

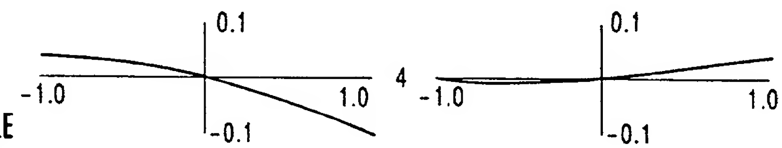


FIG.19D

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 26.3
HORIZONTAL ANGLE OF INCIDENCE

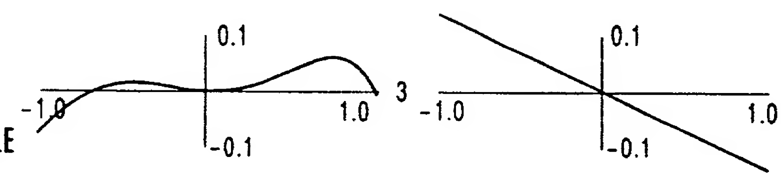


FIG.19E

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

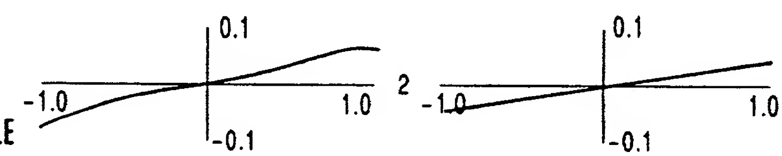


FIG.19F

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y -26.3
HORIZONTAL ANGLE OF INCIDENCE

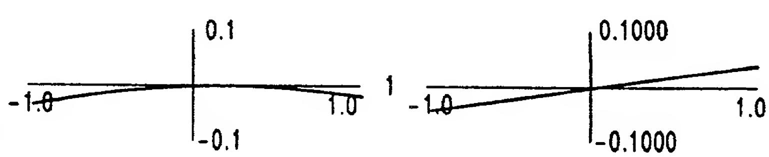


FIG.21A

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE

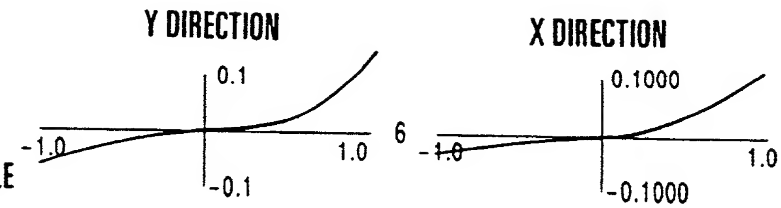


FIG.21B

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

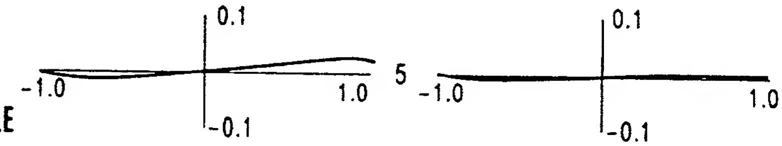


FIG.21C

VERTICAL ANGLE OF INCIDENCE
Ux 24.8
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE

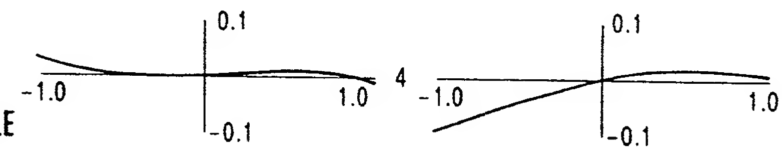


FIG.21D

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 31.7
HORIZONTAL ANGLE OF INCIDENCE

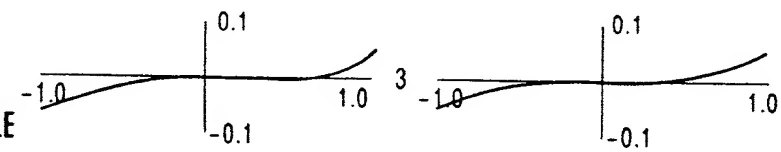


FIG.21E

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy 0
HORIZONTAL ANGLE OF INCIDENCE

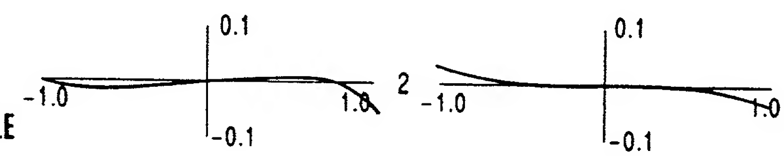
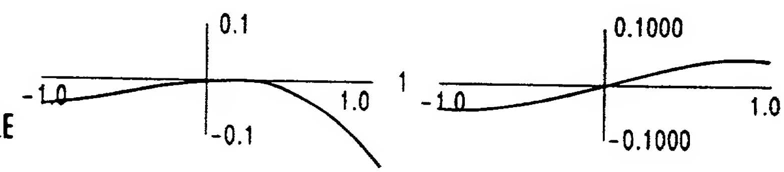


FIG.21F

VERTICAL ANGLE OF INCIDENCE
Ux 0
Uy -31.7
HORIZONTAL ANGLE OF INCIDENCE



Y DIRECTION X DIRECTION

FIG.23A

VERTICAL ANGLE OF INCIDENCE
U_X 24.8
U_Y 31.7
HORIZONTAL ANGLE OF INCIDENCE

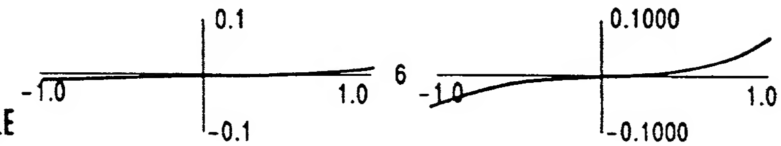


FIG.23B

VERTICAL ANGLE OF INCIDENCE
U_X 24.8
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

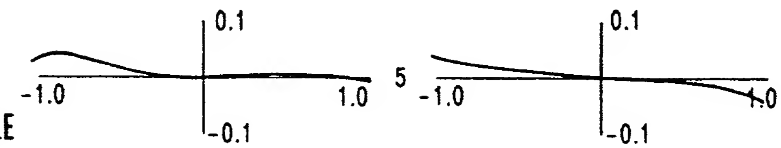


FIG.23C

VERTICAL ANGLE OF INCIDENCE
U_X 24.8
U_Y -31.7
HORIZONTAL ANGLE OF INCIDENCE

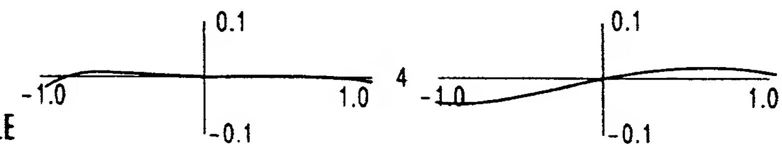


FIG.23D

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 31.7
HORIZONTAL ANGLE OF INCIDENCE

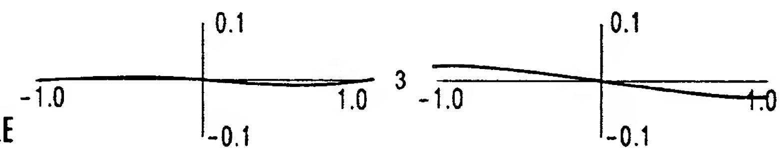


FIG.23E

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y 0
HORIZONTAL ANGLE OF INCIDENCE

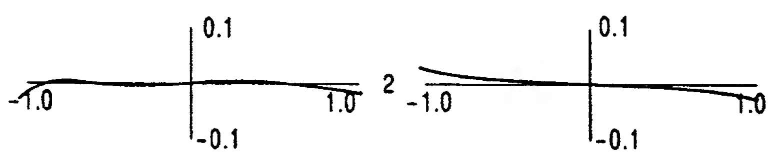


FIG.23F

VERTICAL ANGLE OF INCIDENCE
U_X 0
U_Y -31.7
HORIZONTAL ANGLE OF INCIDENCE

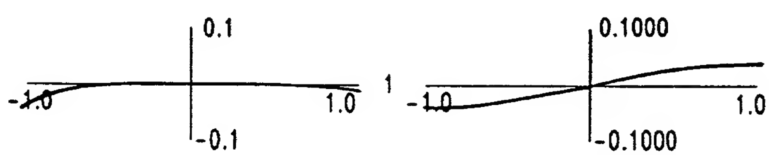


FIG. 24
PRIOR ART

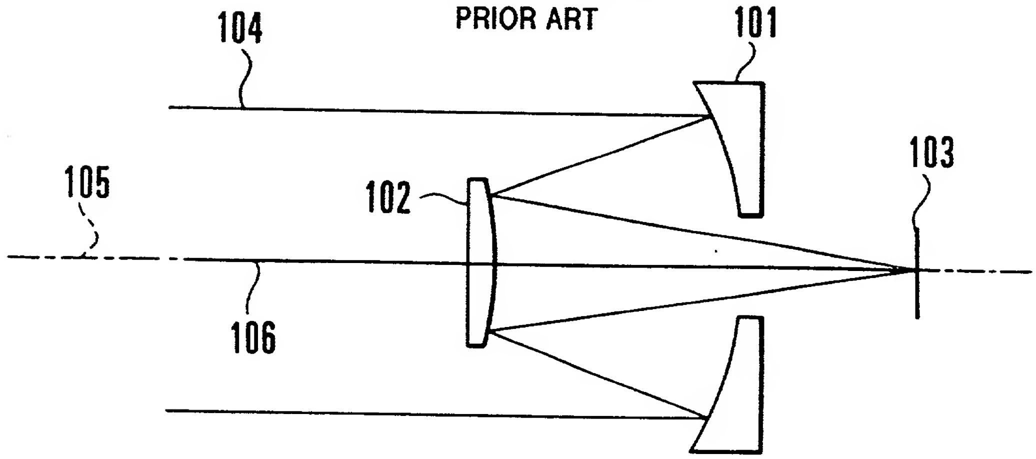
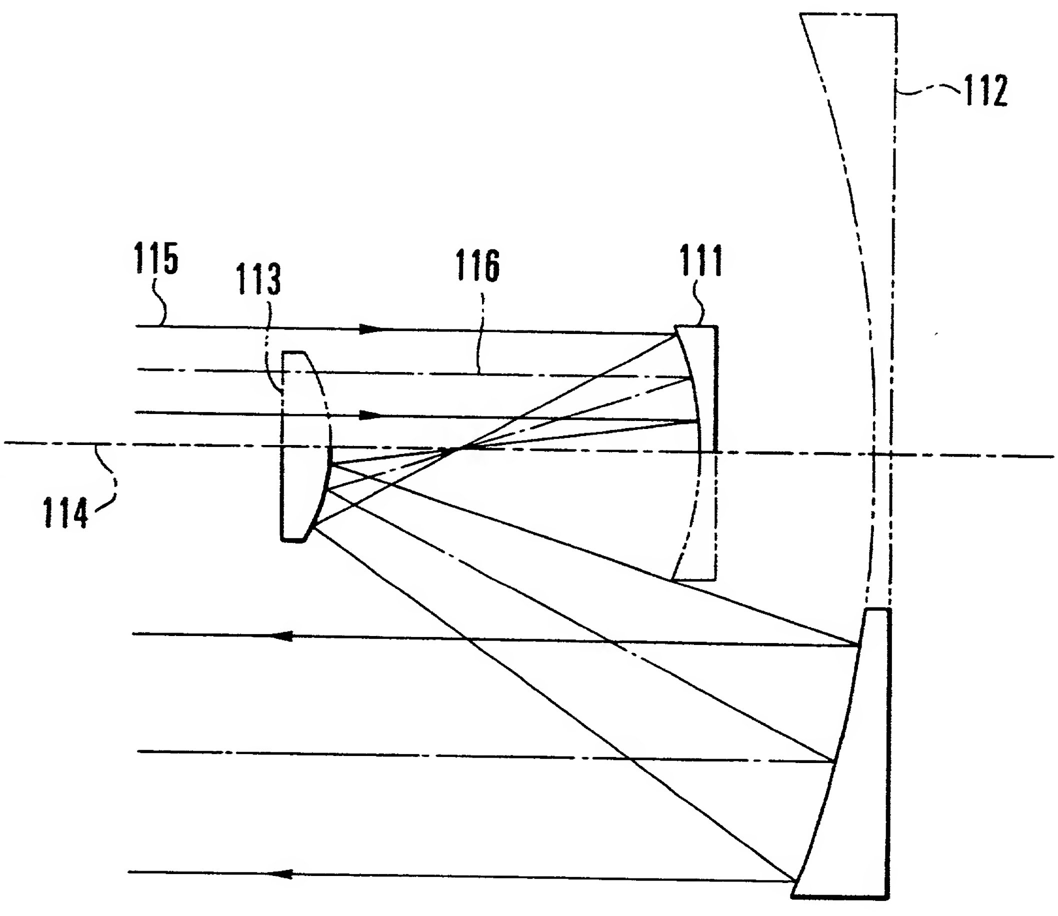
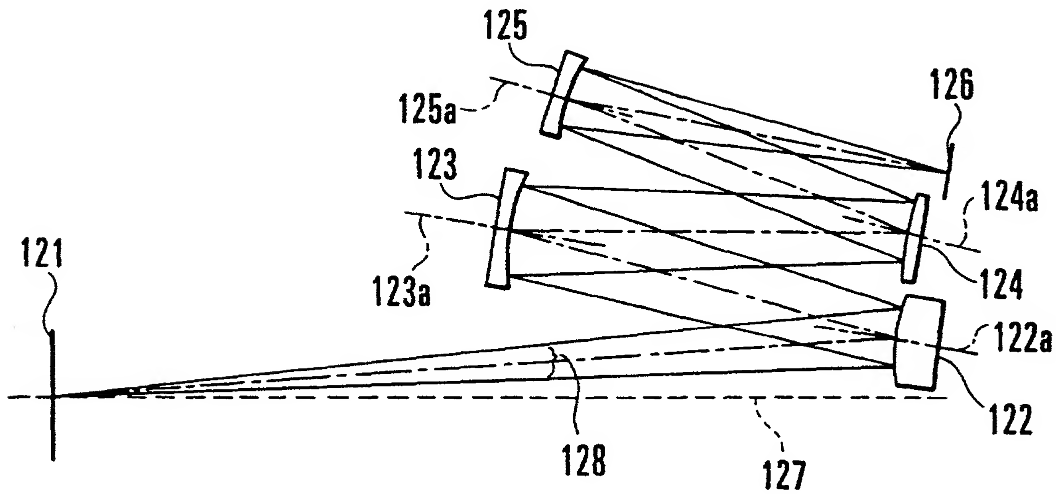


FIG. 25
PRIOR ART

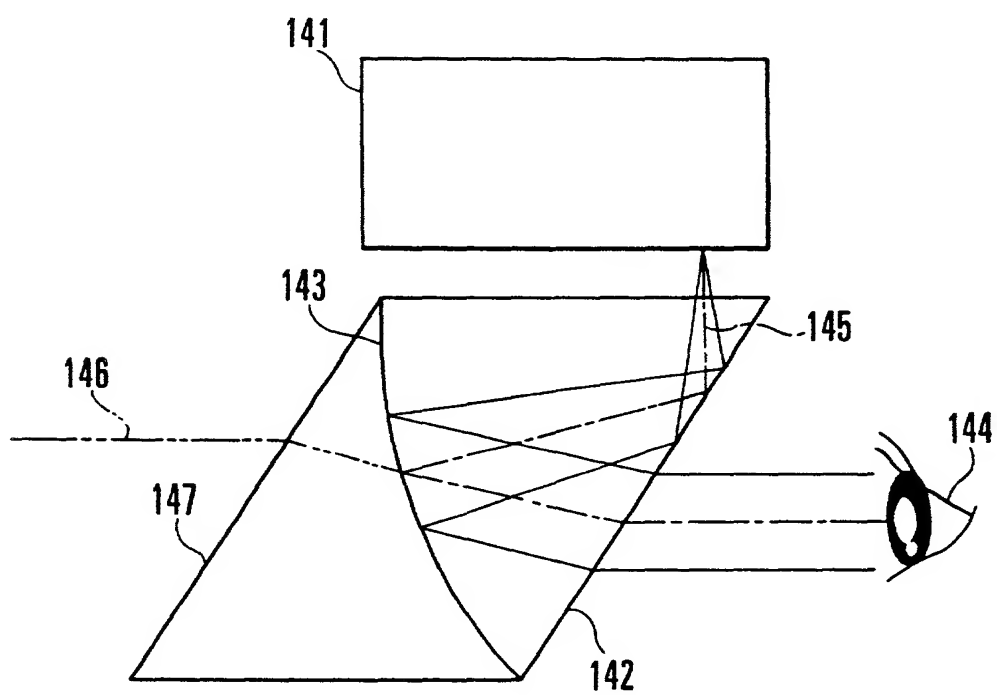


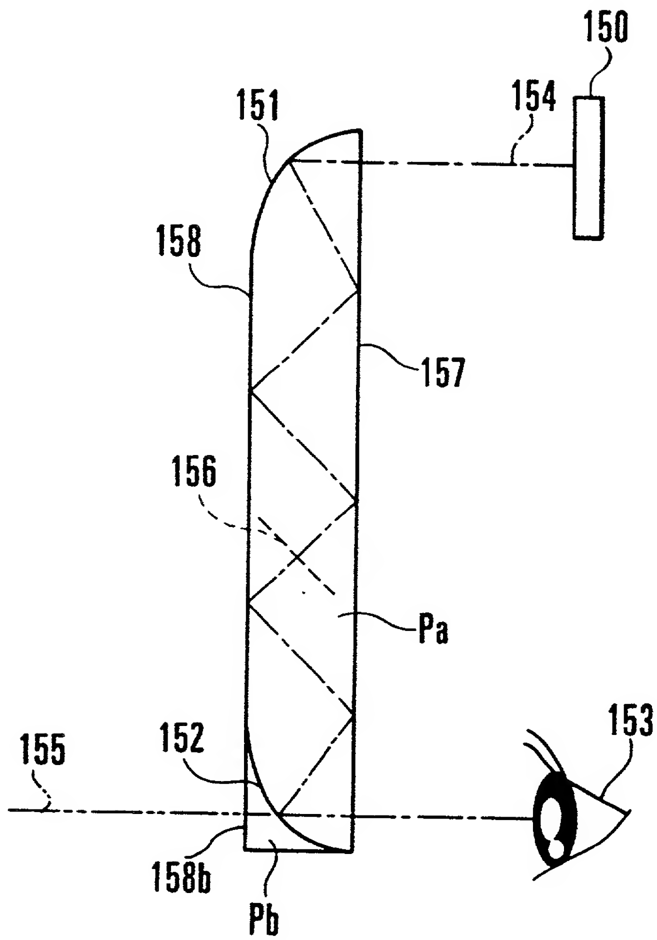
10014305.011402

F I G. 26
PRIOR ART



F I G. 27
PRIOR ART





F I G. 28
PRIOR ART